
KARL
KRUSZELNICKI
PETER
TUTHILL

an
inconvenient
truth
(2006 !)


KARL
KRUSZELNICKI
PETER
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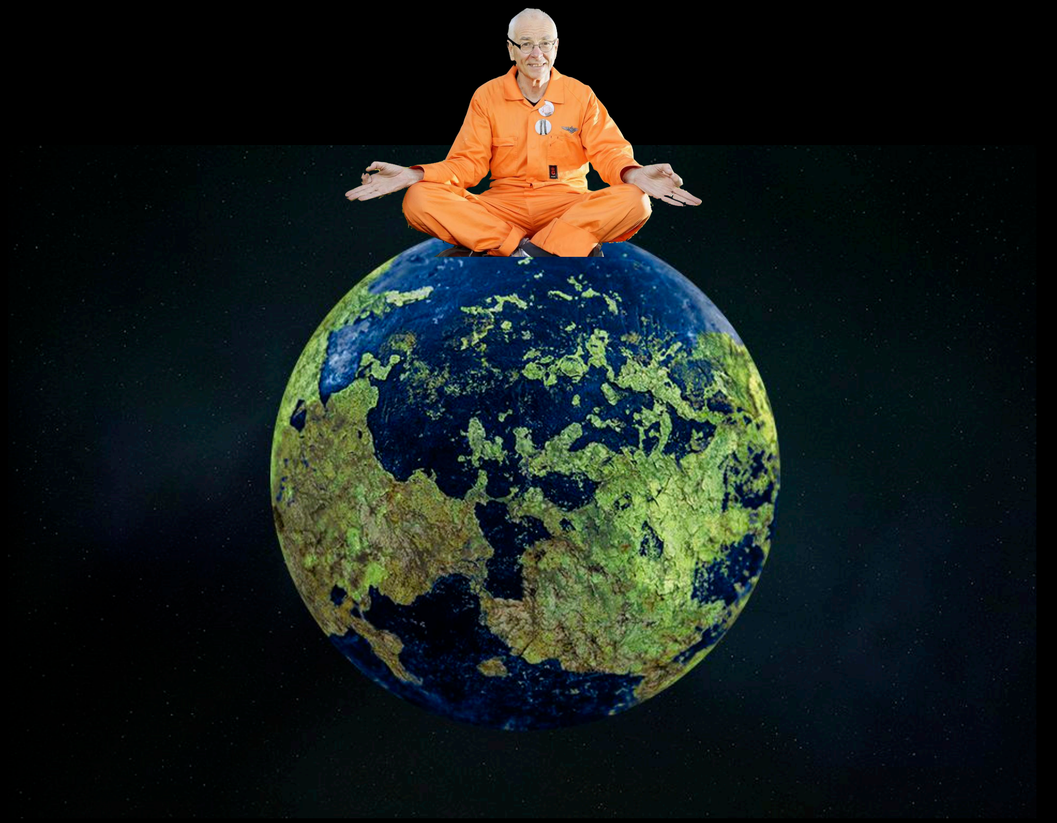
ASTRONOMERS!
YOUR PLANET NEEDS YOU!
KARL KRUSZELNICKI
PETER TUTHILL

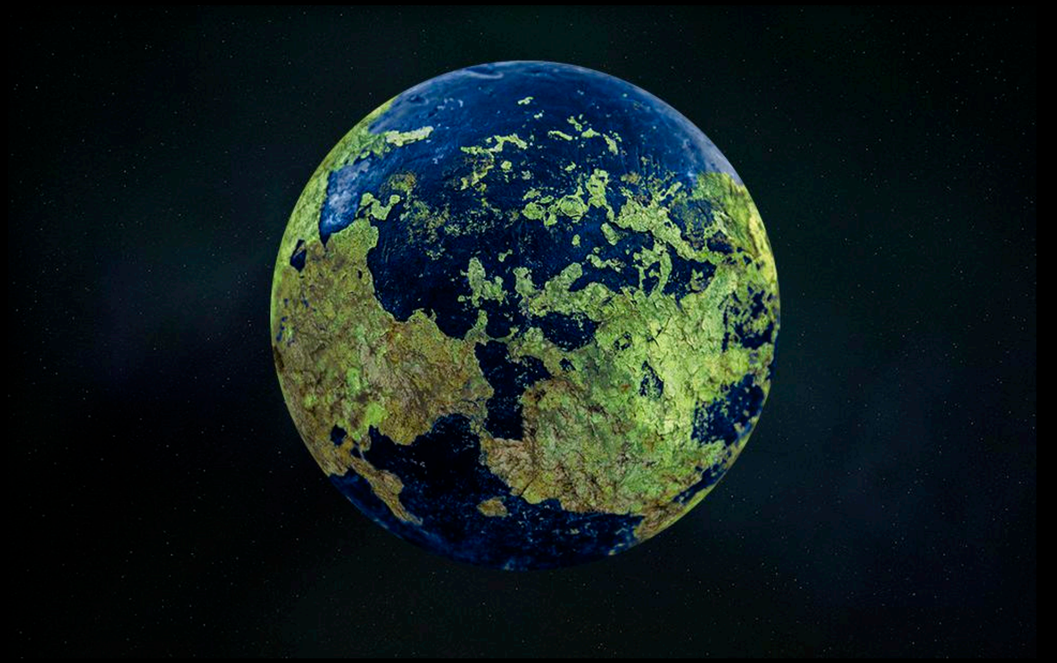

NSW
Transport for NSW
NSW BLUES

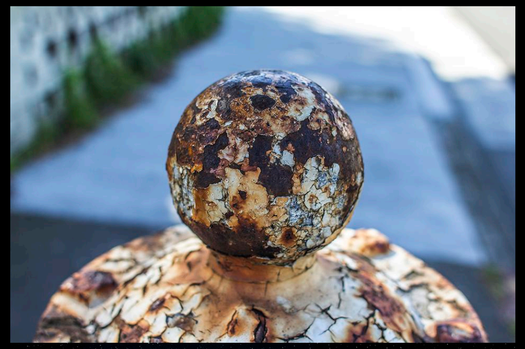
Climate Change

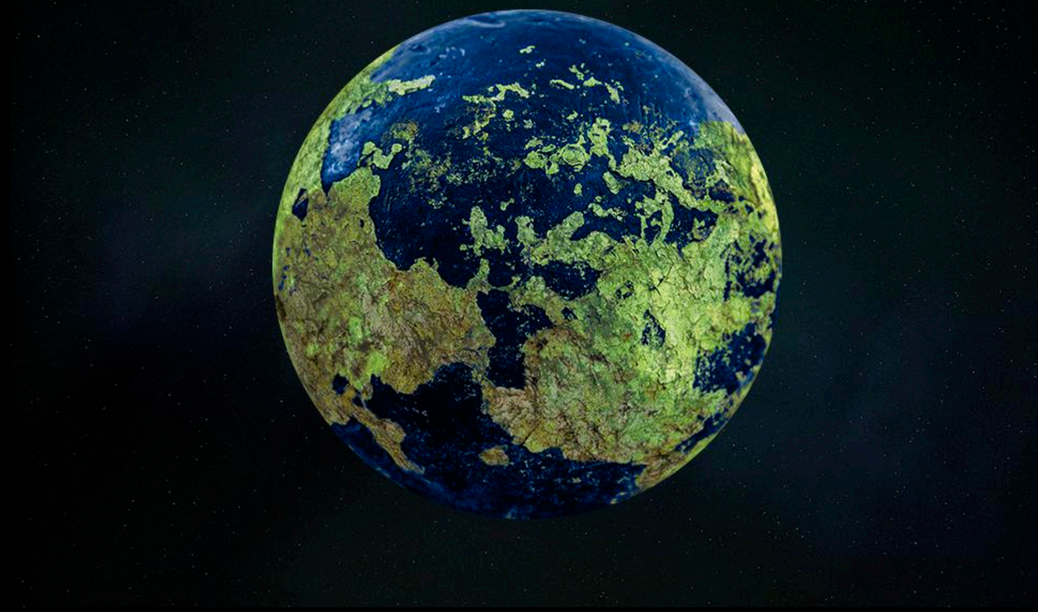

PLAN B




PLAN B







Art Project: SF artist Adam Kennedy

Why Astronomy?

- You have a *new* story to tell
- Trusted voice (impartial)
- Climate Change = Predict Future
- Nobody has Crystal Ball
- (Or do they?)

Go back to the ORIGIN!

Why Astronomy?

- Astronomers:
  - Get Planetary Energy Budgets
  - Test climate models beyond Earth
  - Have witnessed climate change in our Solar System

1) The Blue Marble

- Planetary Habitability

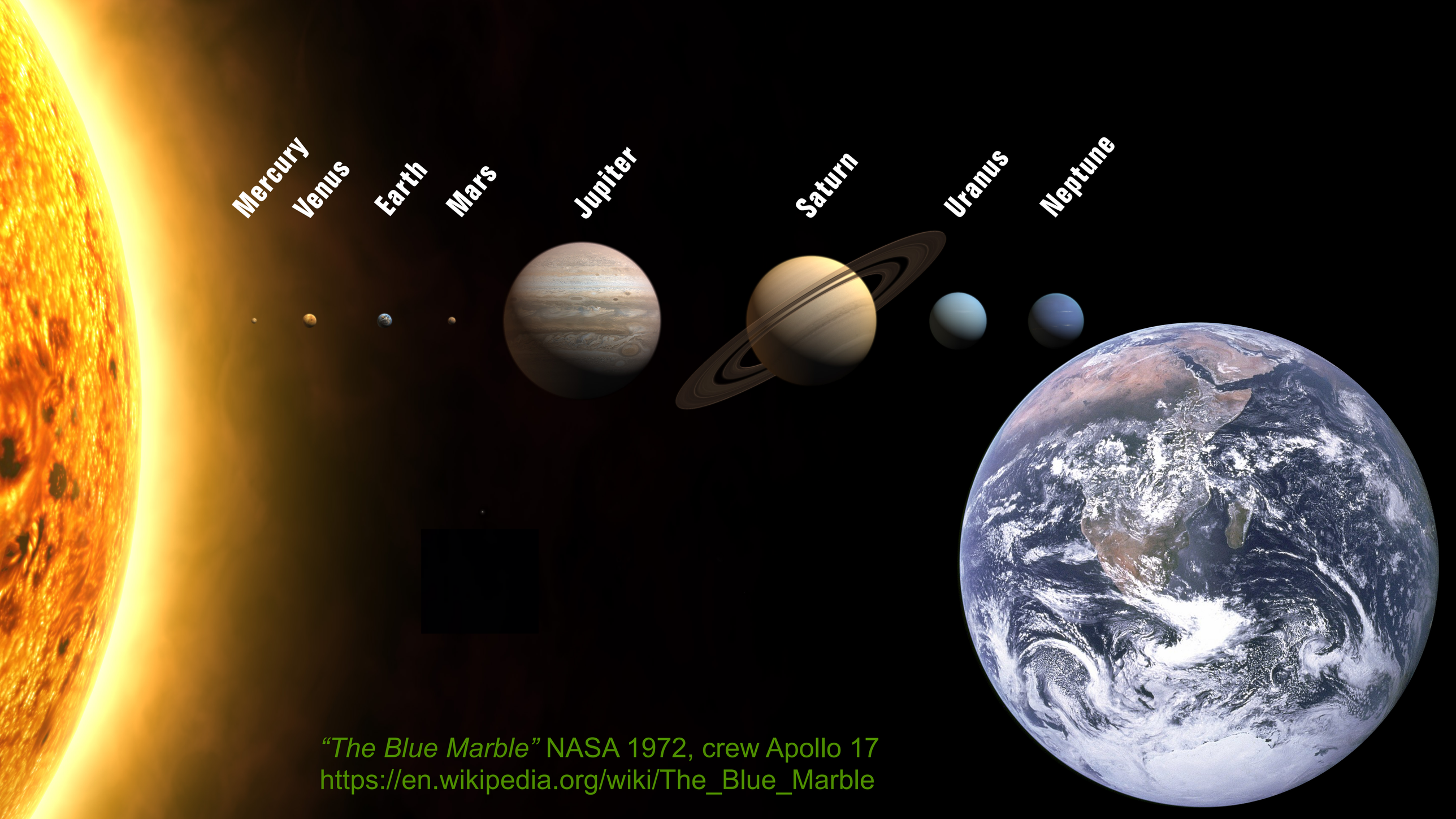
2) Our Solar System: A Morality Play

- The Climate Catastrophes next door

3) The Black Marble

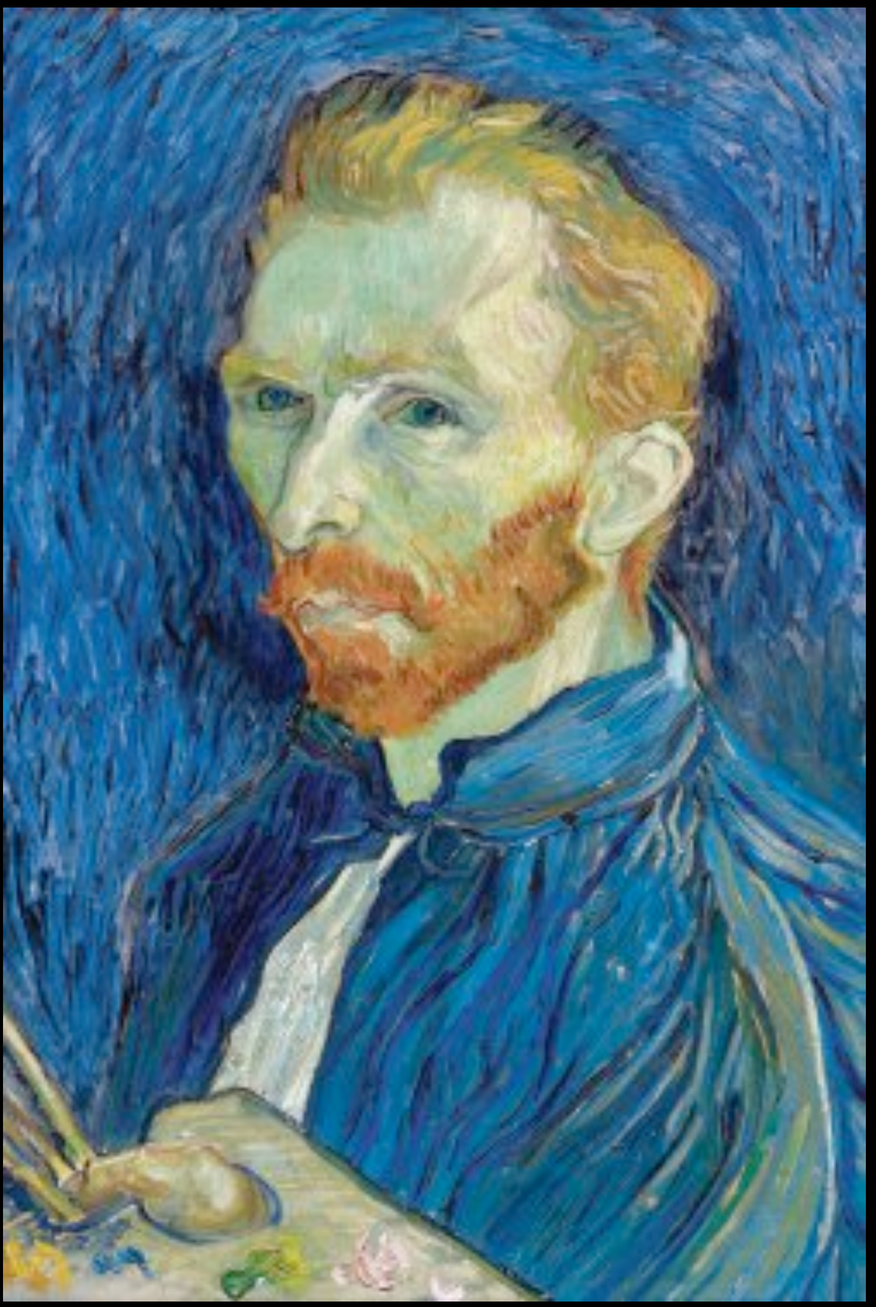
- Where we're heading today

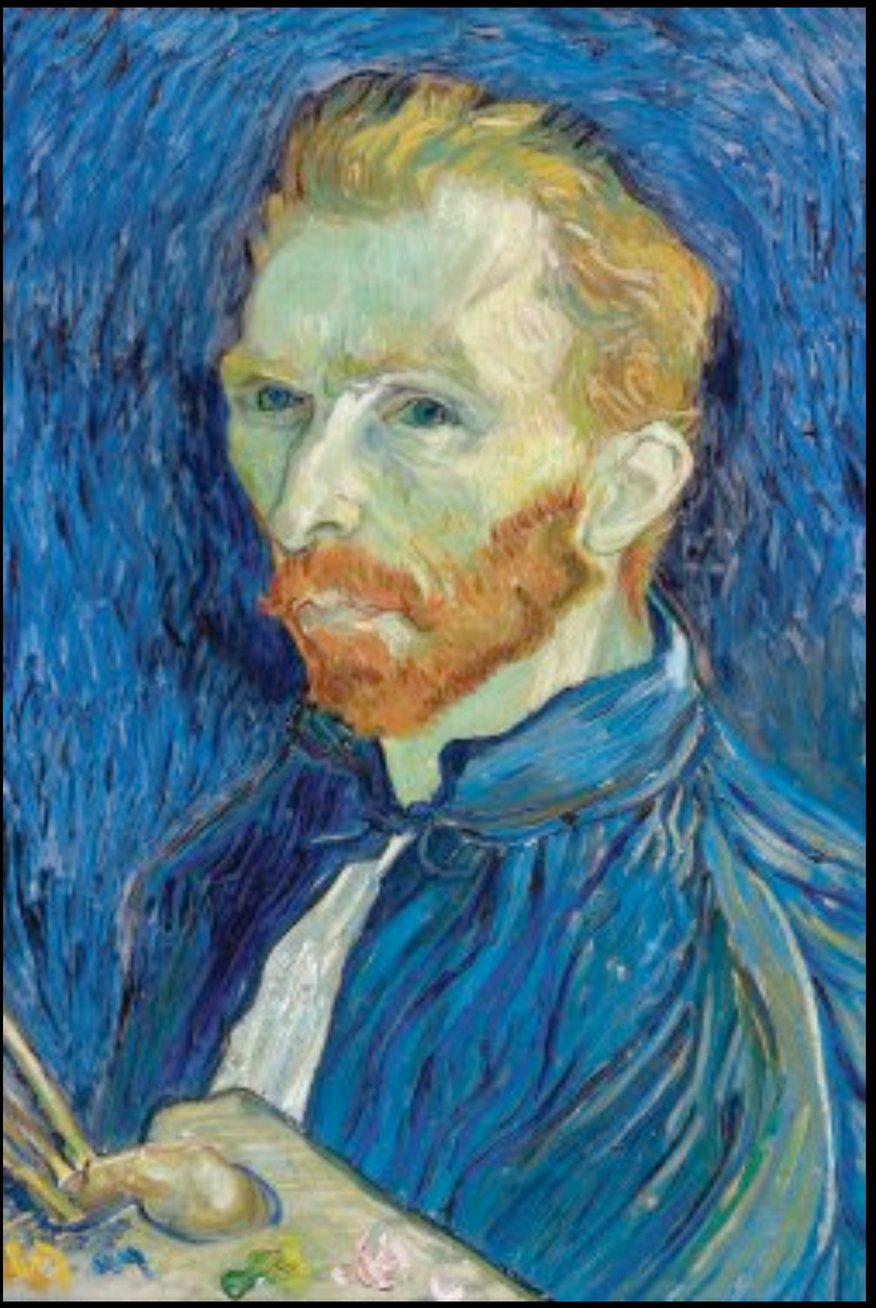
1
Blue Marble



"The Blue Marble" NASA 1972, crew Apollo 17
https://en.wikipedia.org/wiki/The_Blue_Marble

Leonardo da Vinci
Renaissance
genius
1452-1519





Blue Marble - 1

- Sun ~ 10^{26} Watts, in all directions
- The sunlit face of the Earth intercepts ~ $1/10^{9}$ ~ 40,000 TW
- Humanity uses ~20 TW (everything)
- How to: Planetary Energy Budget


A Star

M Star

A Star

The Sun
G Star

M Star

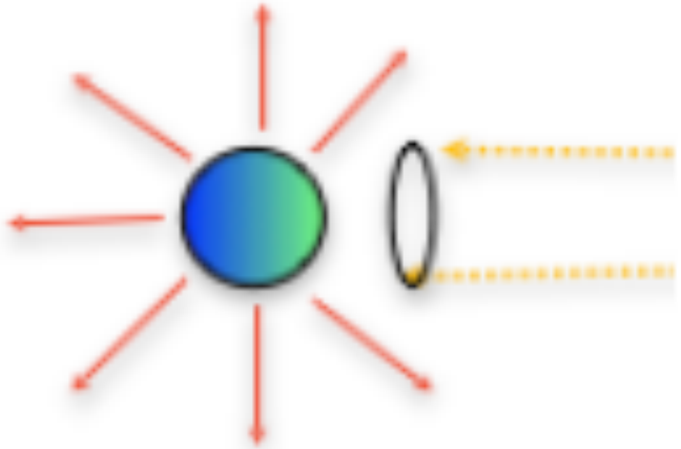
HOT

COOL

Balancing A Planetary Budget

Energy Out = Energy In

Energy leaving (heat radiation to deep space)

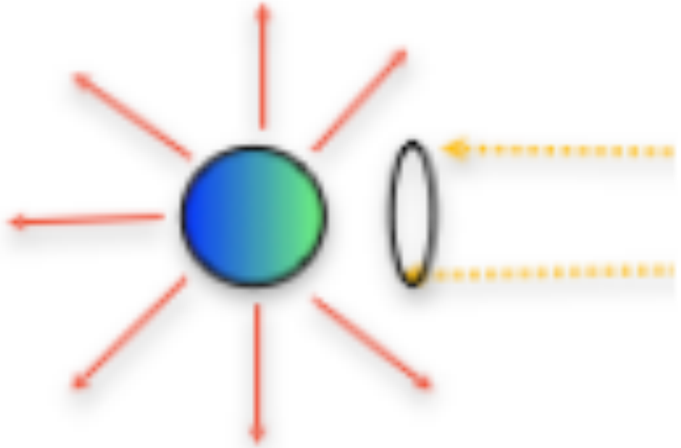


Energy arriving (Sunlight on day-side of planet)

Energy Out = Energy In

$$4\pi R^2 \sigma T_e^4 = S_0 (1 - \alpha) \pi R^2$$

Energy leaving (heat radiation to deep space)



Energy arriving (Sunlight on day-side of planet)

Energy Out = Energy In

$$4\pi R^2 \sigma T_e^4 = S_0 (1 - \alpha) \pi R^2$$

Sunlit face

Surface Area of Earth

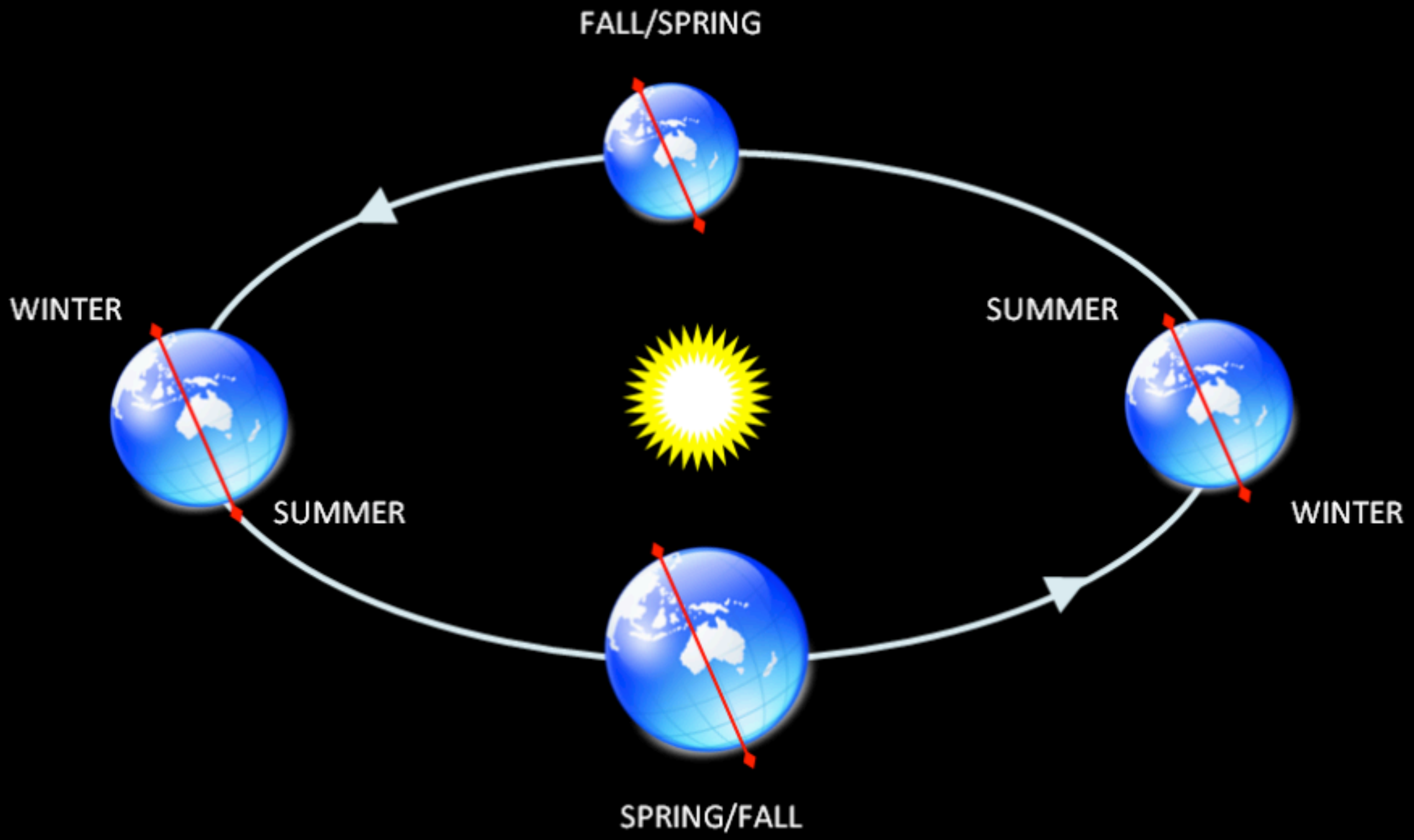
Temp of Earth

Solar Constant 1,361 W/m²

Albedo/ Reflectivity of Earth

Short Term Solar Forcing

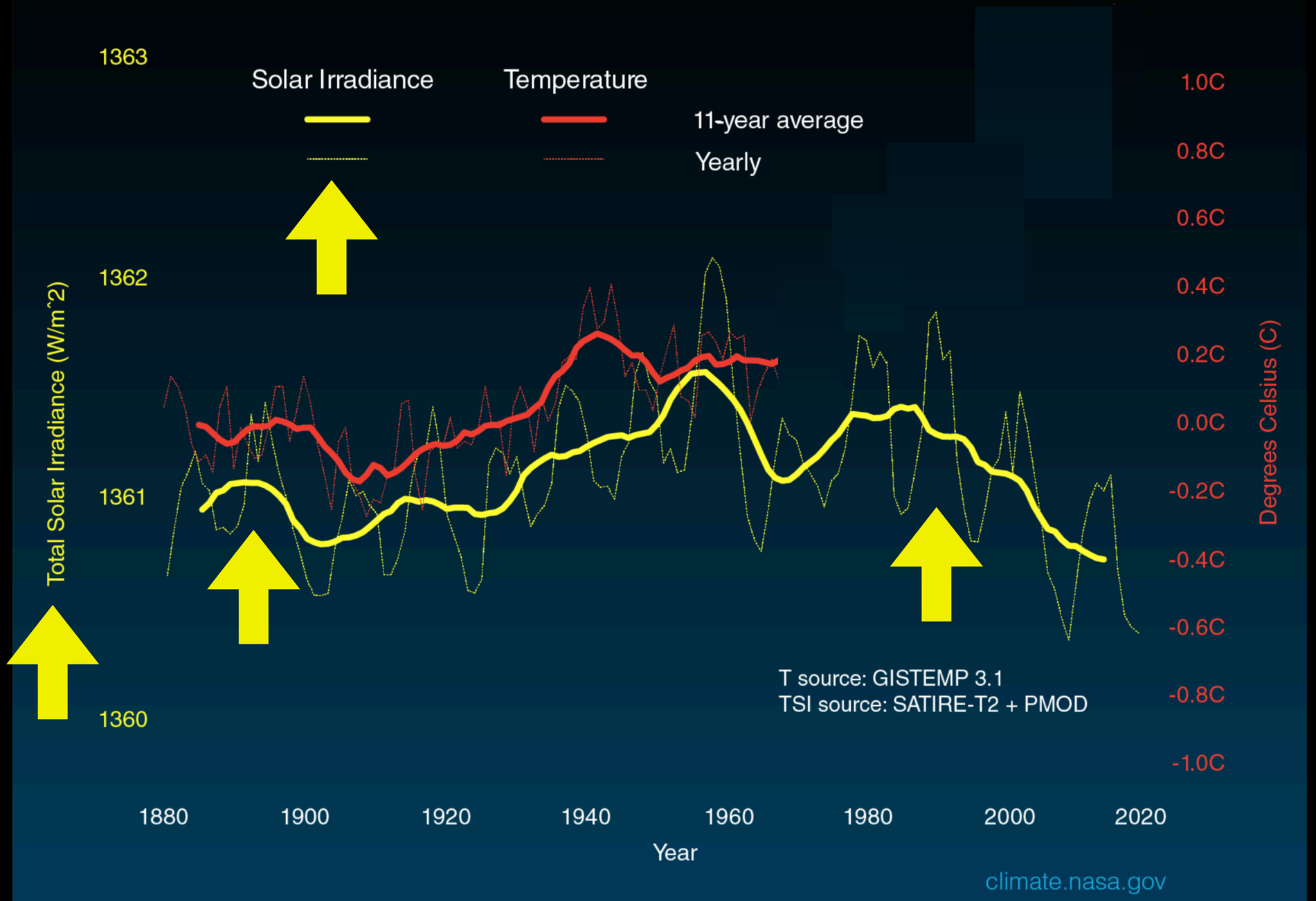
- Seasons, N/S Hemisphere Insolation
- Earth's ellipticity → (Jan 8% > July)
- 22-year Solar Cycle
- Typical variation ~0.1% in Sun's output over a decade


FALL/SPRING
WINTER
SUMMER
SUMMER
WINTER
SPRING/FALL

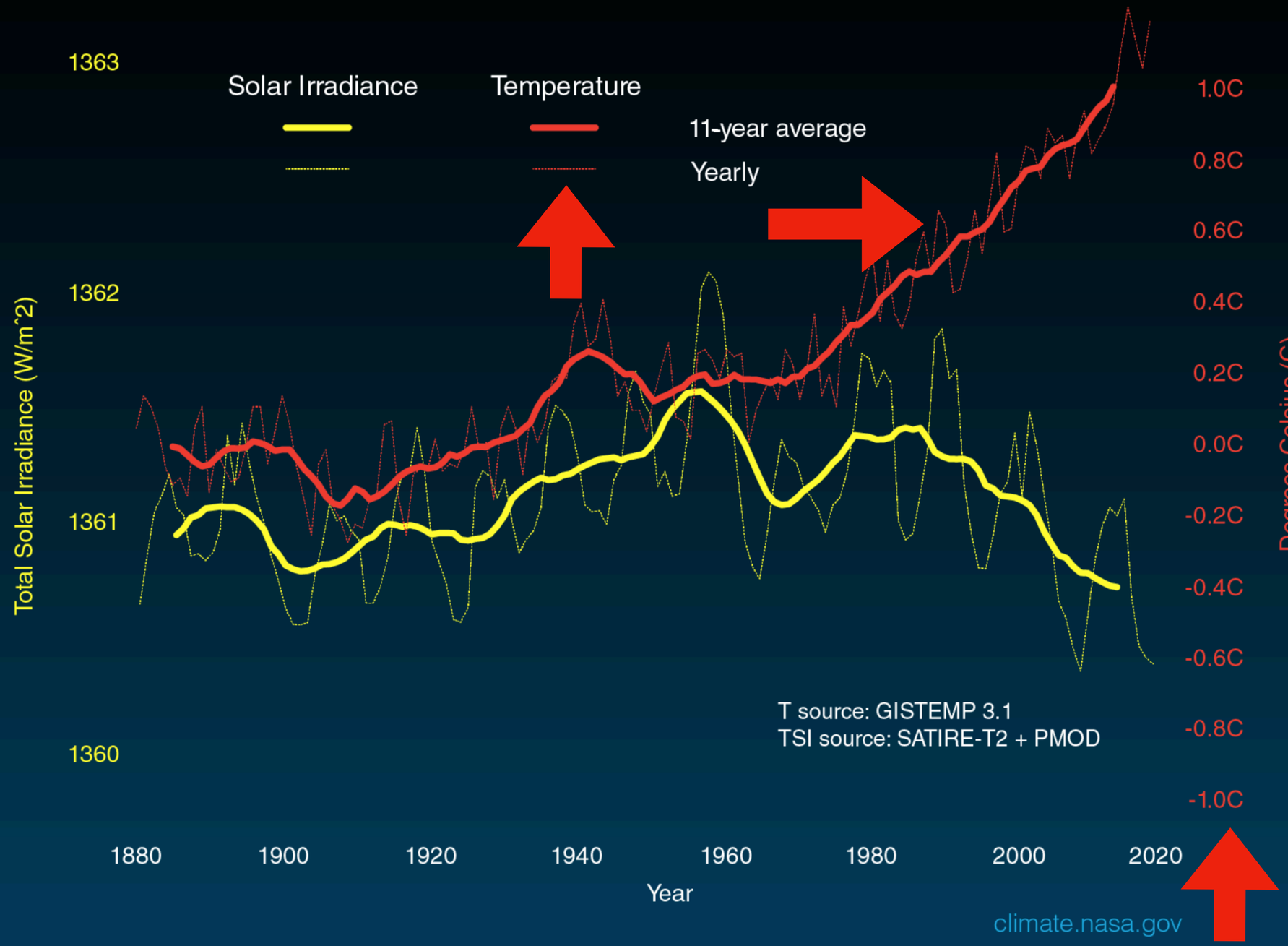
Long Term Solar Forcing

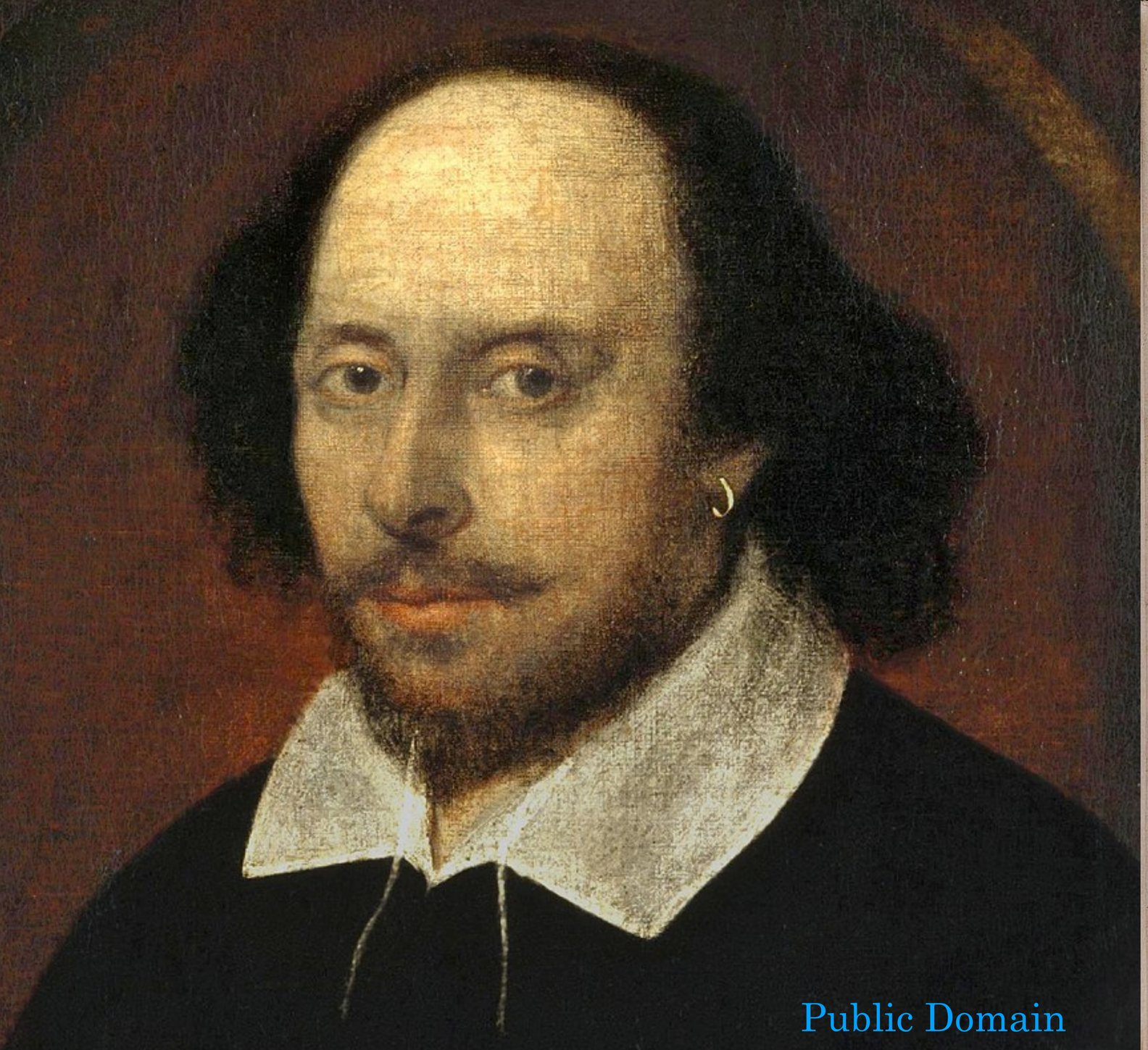
- Milankovitch Cycles, over 10s-100s of thousands of years
- Long-term changes in solar activity/ output (eg, “Maunder Minimum” of Little Ice Age of 17th Century)

Temperature vs Solar Activity



Temperature vs Solar Activity





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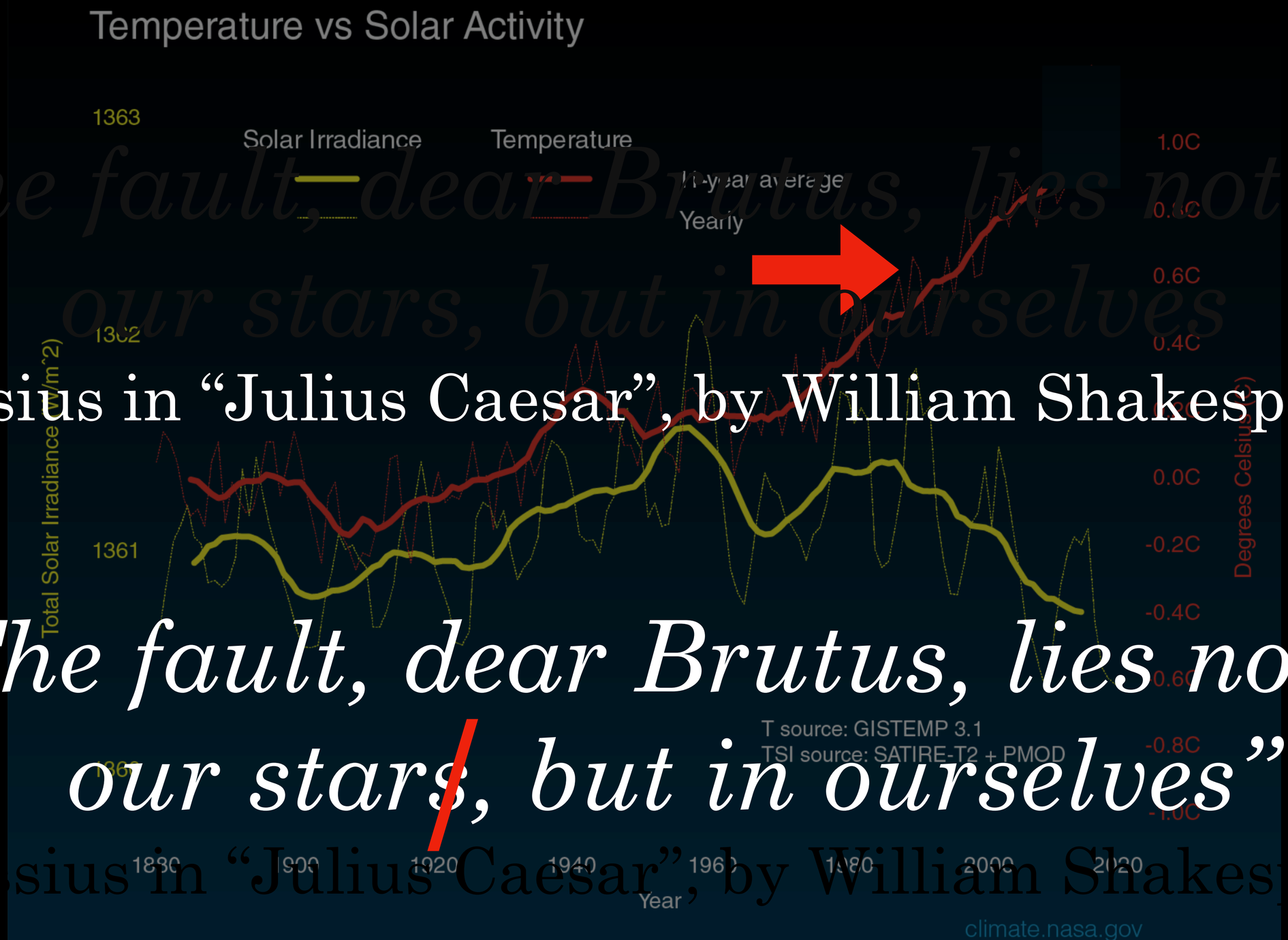
LONDON

Printed by Isaac Iaggard, and Ed. Blount. 1623.



Cassius in “Julius Caesar”, by William Shakespeare

“The fault, dear Brutus, lies not in our stars, but in ourselves”

Very Long Term Solar Forcing

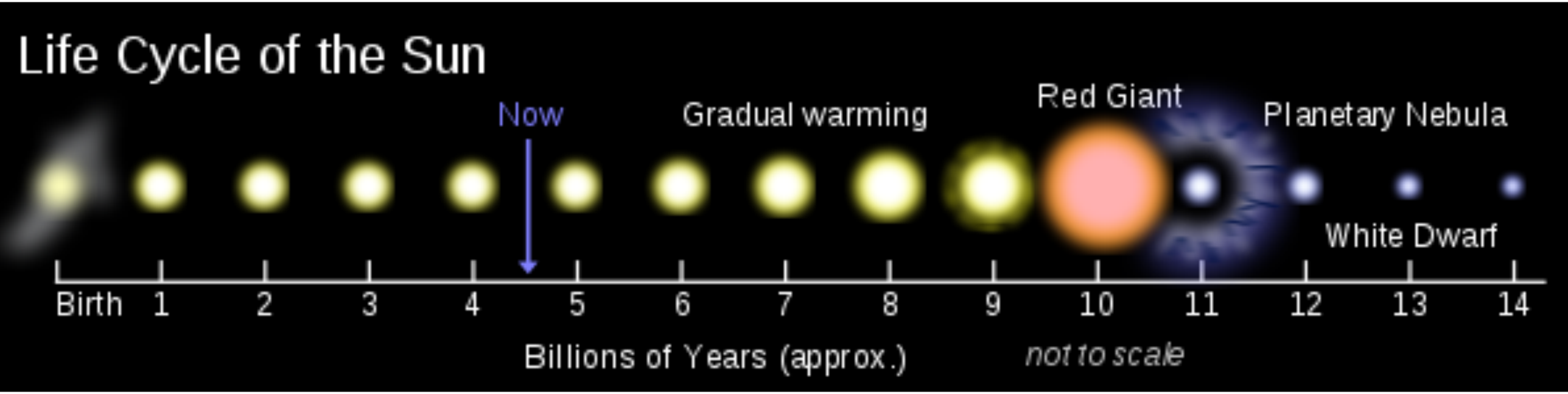


Image Credit: Wikipedia commons

Birth of Solar System, Sun, Earth

Sun was 30% less bright

How did Young Earth avoid freezing?

Very Long Term Solar Forcing

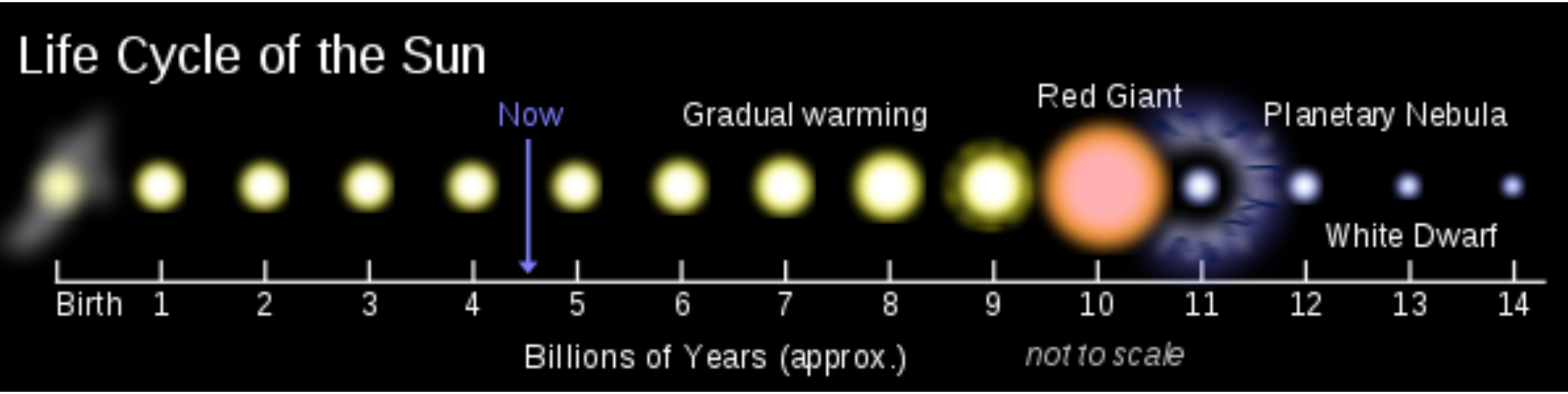


Image Credit: Wikipedia commons

Today, “nice and comfy”

Very Long Term Solar Forcing

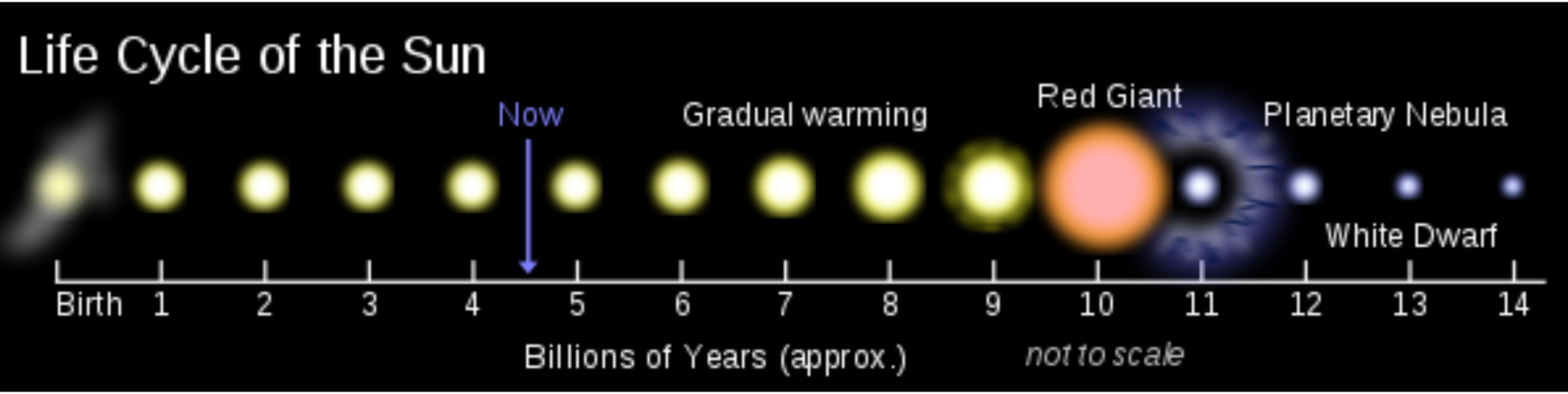


Image Credit: Wikipedia commons

Sun heats up, ~ 1 Billion Years

Habitable Zone leaves Earth

End of biosphere, Runaway Greenhouse, Oceans boil

Very Long Term Solar Forcing

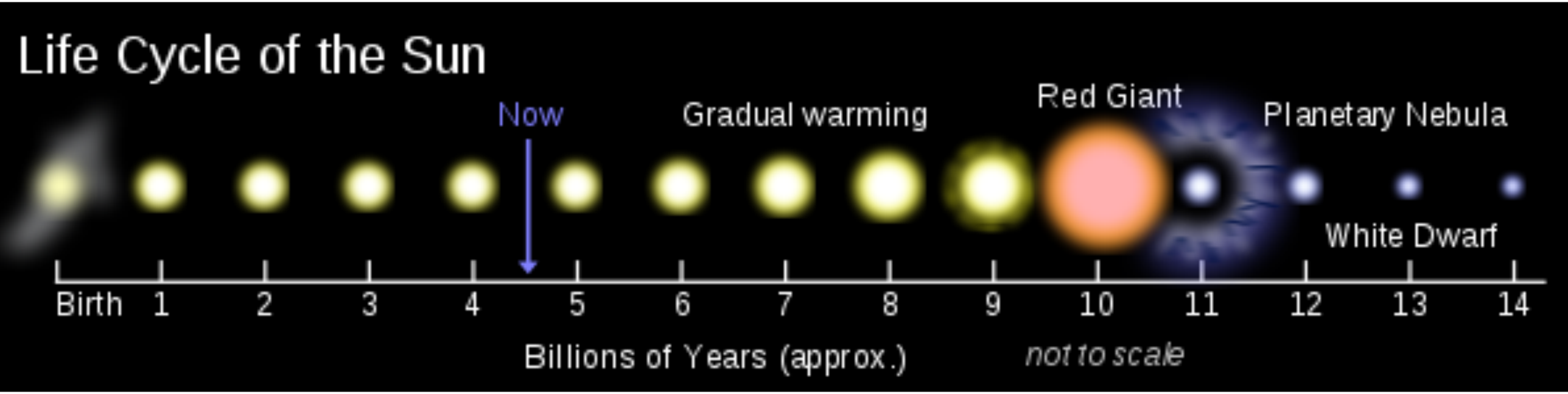


Image Credit: Wikipedia commons

Sun → Red Giant

Inner Solar System consumed

Very Long Term Solar Forcing

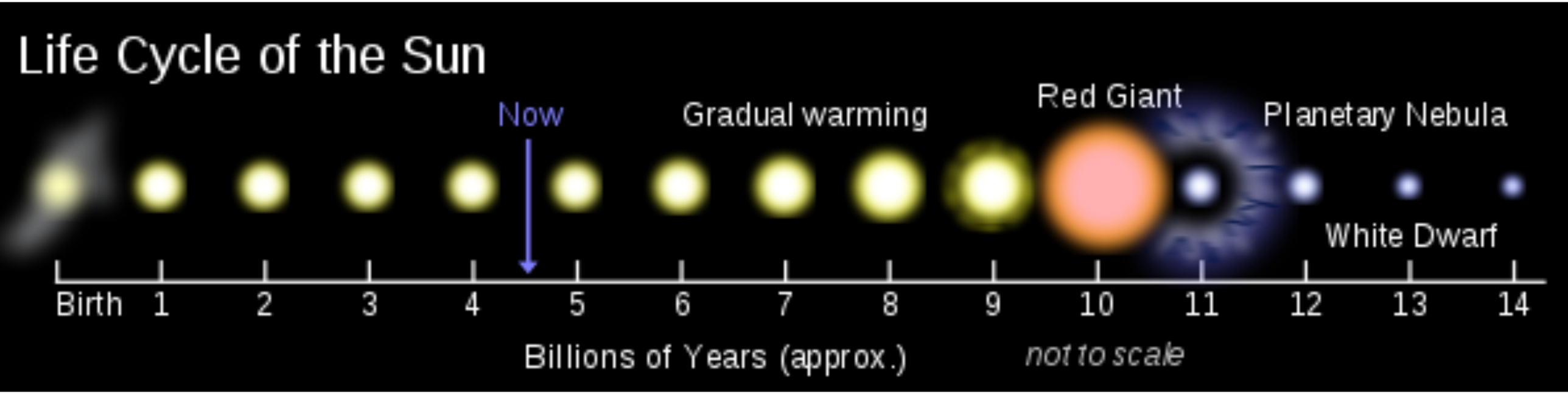


Image Credit: Wikipedia commons

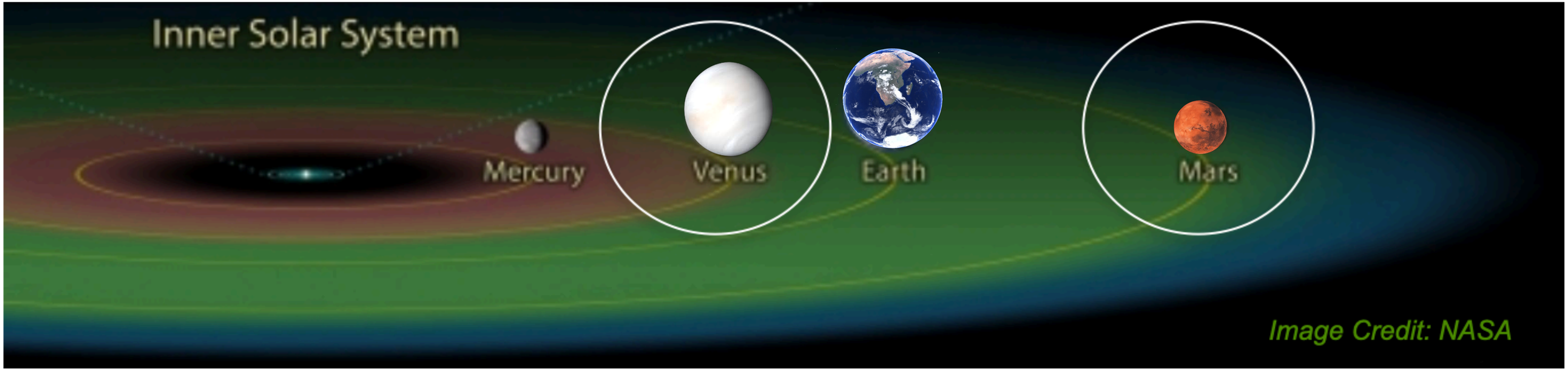
White Dwarf

Trillions of Years

2

A Solar System Morality Play

Comparative Planetology: A Climate Morality Play?



Comparative Planetology: A Climate Morality Play?

Temperature of a Planet?

Temperature of a Planet?

- 0 Distance from its star(s)
- 1 Blackbody (ie, black ball of iron - absorbs all radiation, no atmosphere)
- 2 +Reflectivity/albedo (no atmosphere)
- 3 +Atmosphere (realistic)

Blackbody Temperature=(Black Ball of Iron, No Atmosphere)

+54C +6C -48C

Blackbody Temperature=(Black Ball of Iron, No Atmosphere)

+54C +6C -48C

Equilibrium Temperature = (Albedo/Refectivity, No Atmos.)

-41C **(-95)** -18C **(-24)** -64C **(-16)**

Blackbody Temperature=(Black Ball of Iron, No Atmosphere)

+54C +6C -48C

Equilibrium Temperature = (Albedo/Refectivity, No Atmos.)

-41C **(-95)** -18C **(-24)** -64C **(-16)**

Observed Temperature = (Albedo/Reflectivity+Atmosphere)

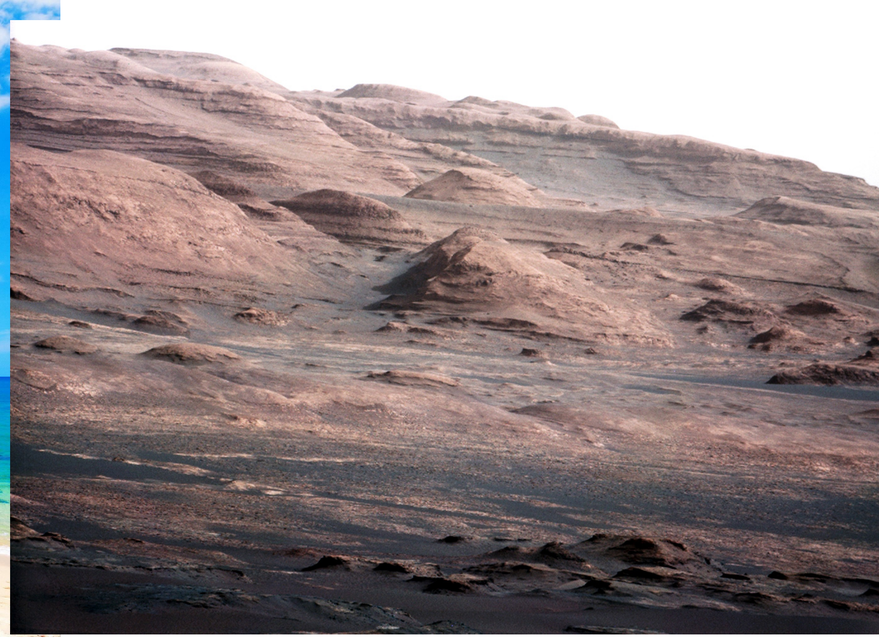
+460C **(+500)** +15C **(+33)** -58C **(+8)**

Temperature of a Planet?

Both Venus & Mars, in the past, had a habitable climate (Water? Mars Y. Venus ?)

Temperature of a Planet?

Both Venus & Mars have suffered Runaway Climate Change → very inhospitable



Venus

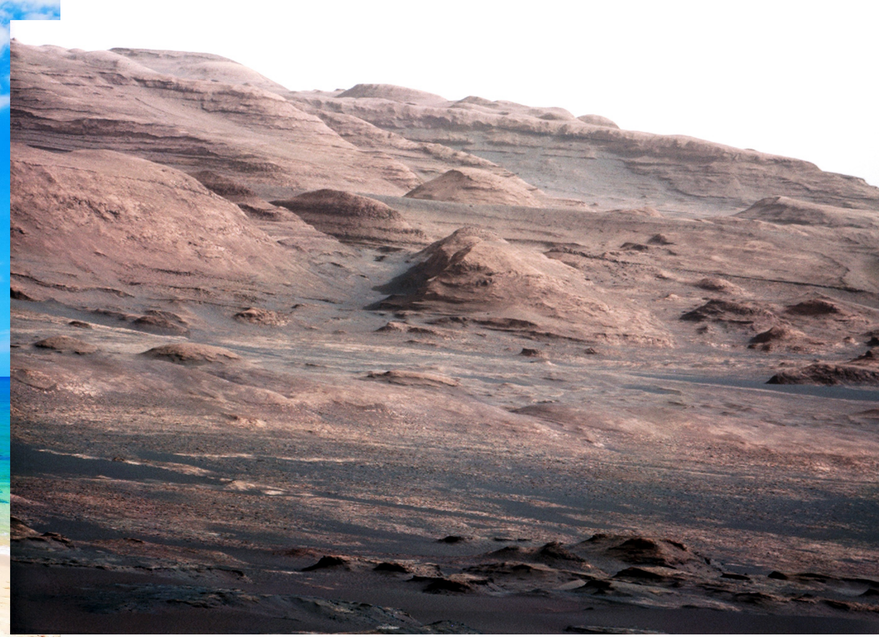
+460 °C

Nice &

Balmy

Mars

-60 °C



Venus *Nice &* *Mars*

+460 °C *Balmy* *-60 °C*

Venus / *Mars* *-What went wrong?*

What is Earth's "secret sauce"?

Venus: What went wrong?

Early Venus

- ? Wet & Temperate (High Albeido)
- ? Mild climate for ~billions of years?
- ? How? Slow rotation
- ? Dayside cloud shield
- ? Nightside clear !

Venus: mid-life crisis

- Too close to sun (↑↑ Solar Energy)
- ? No active plate tectonics
- ↑↑ Volcanic Events → ↑CO_2 + ↑H_2O
- Oceans boiled, runaway greenhouse
- ↓↓ rotation, no magnetosphere
- Solar wind strips hydrogen

Climate Change:

- **Catastrophic**
  (any biosphere destroyed)
- **Irreversible**
  (Hydrogen lost to space)

Mars: What went wrong?

Early Mars

- Actual physical evidence →
- Surface water (rivers, lakes)
- Definitely had a temperate climate

Mars: The end of summer

1. Too small - low gravity
   A. ↓ internal heat ↓ volcanoes
      no recycling of atmosphere
   B. ↓ liquid core ↓ mag field →
      solar wind erodes atmosphere
2. Too far from Sun ↓ Solar Flux

Climate Change:

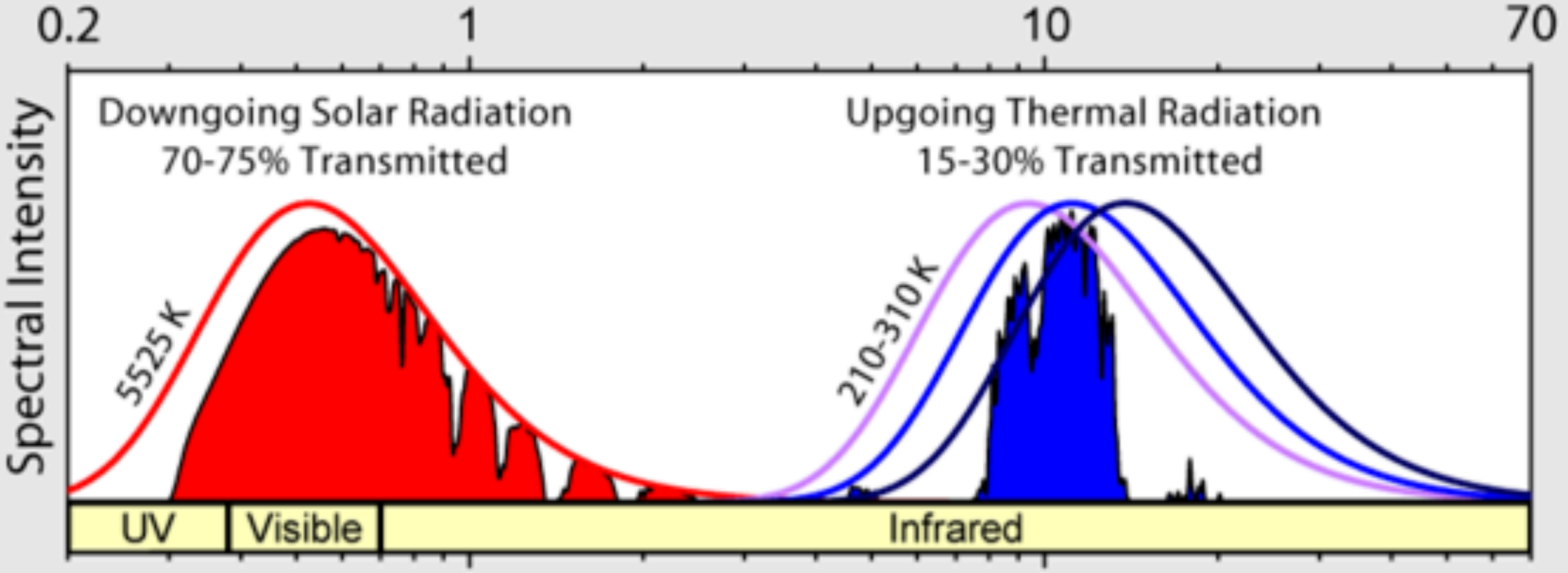
- **Catastrophic**
  (any biosphere destroyed)
- **Irreversible**
  (Volatiles lost to space)

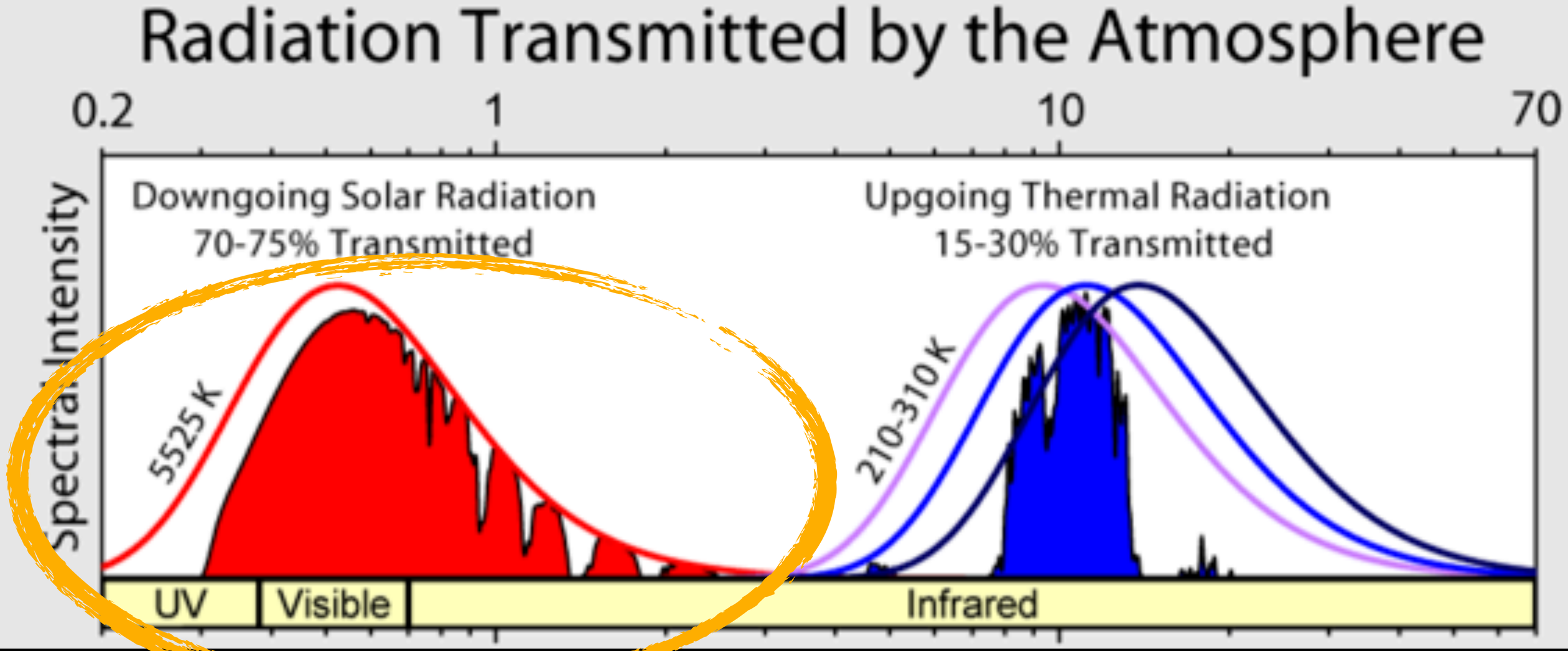
Earth

What sets Earth's climate?

- Atmosphere traps, and retains, heat
- Atmosphere acts like one-way valve
- ~70% of incoming sunlight absorbed
- ~30% of Earth's infrared heat can escape
- (Changes in CO2 alter set-point of Earth's "thermal blanket")

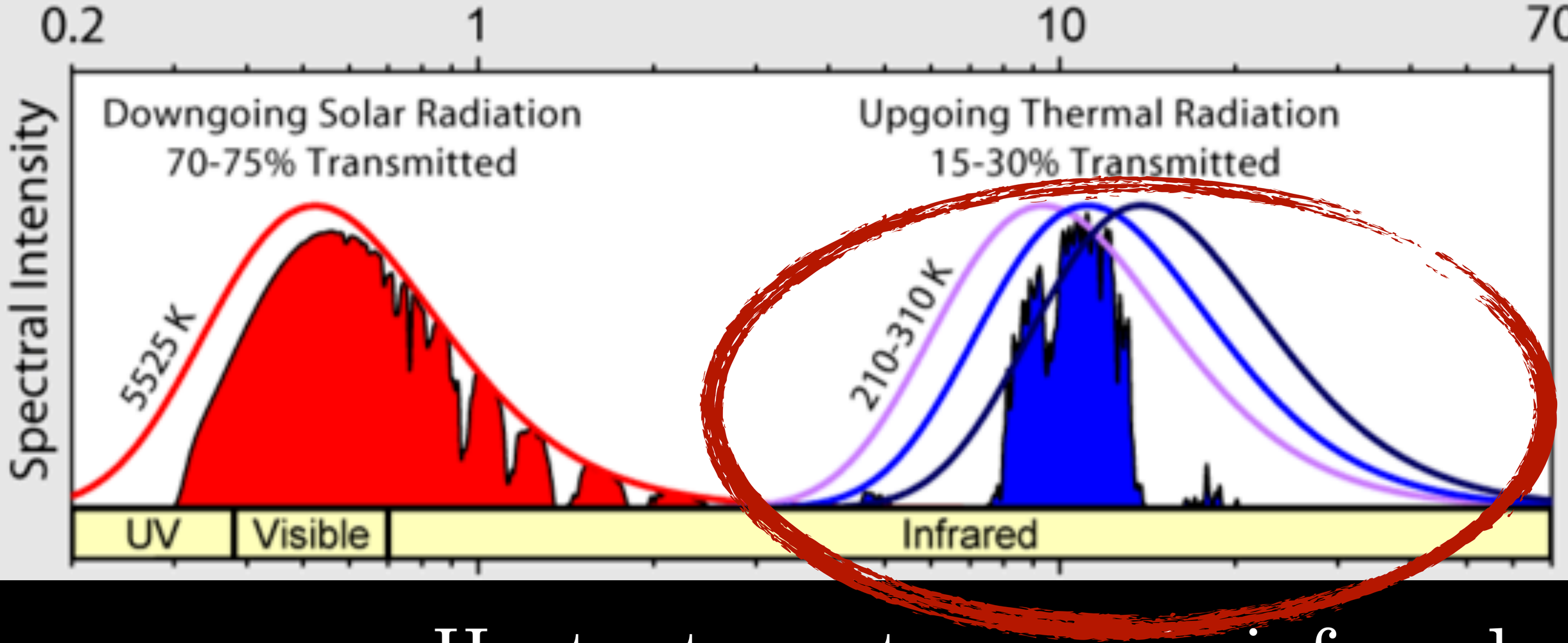
Radiation Transmitted by the Atmosphere



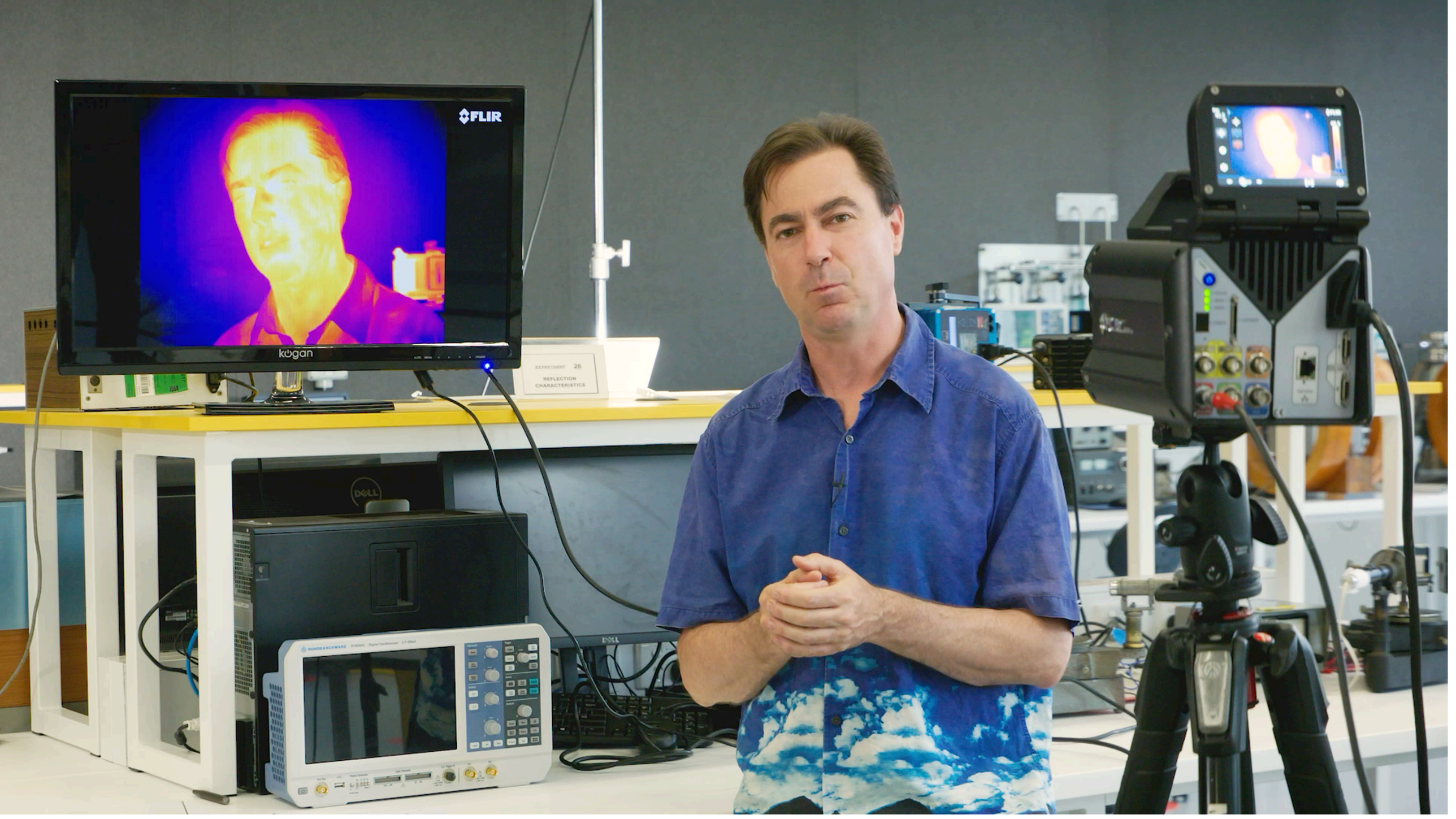


Sunlight arrives in the visible.
Most gets down to ground level.

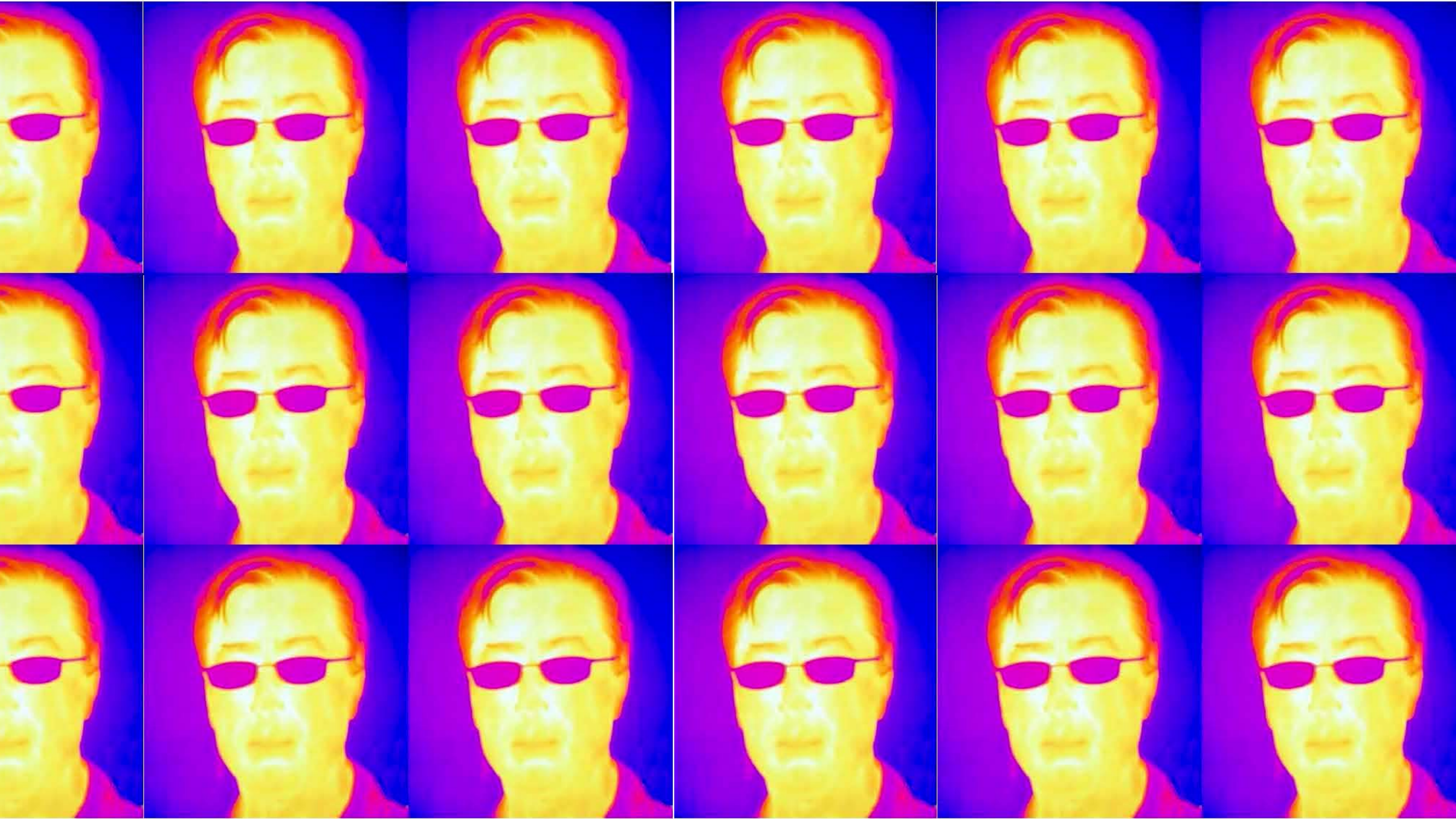
Radiation Transmitted by the Atmosphere

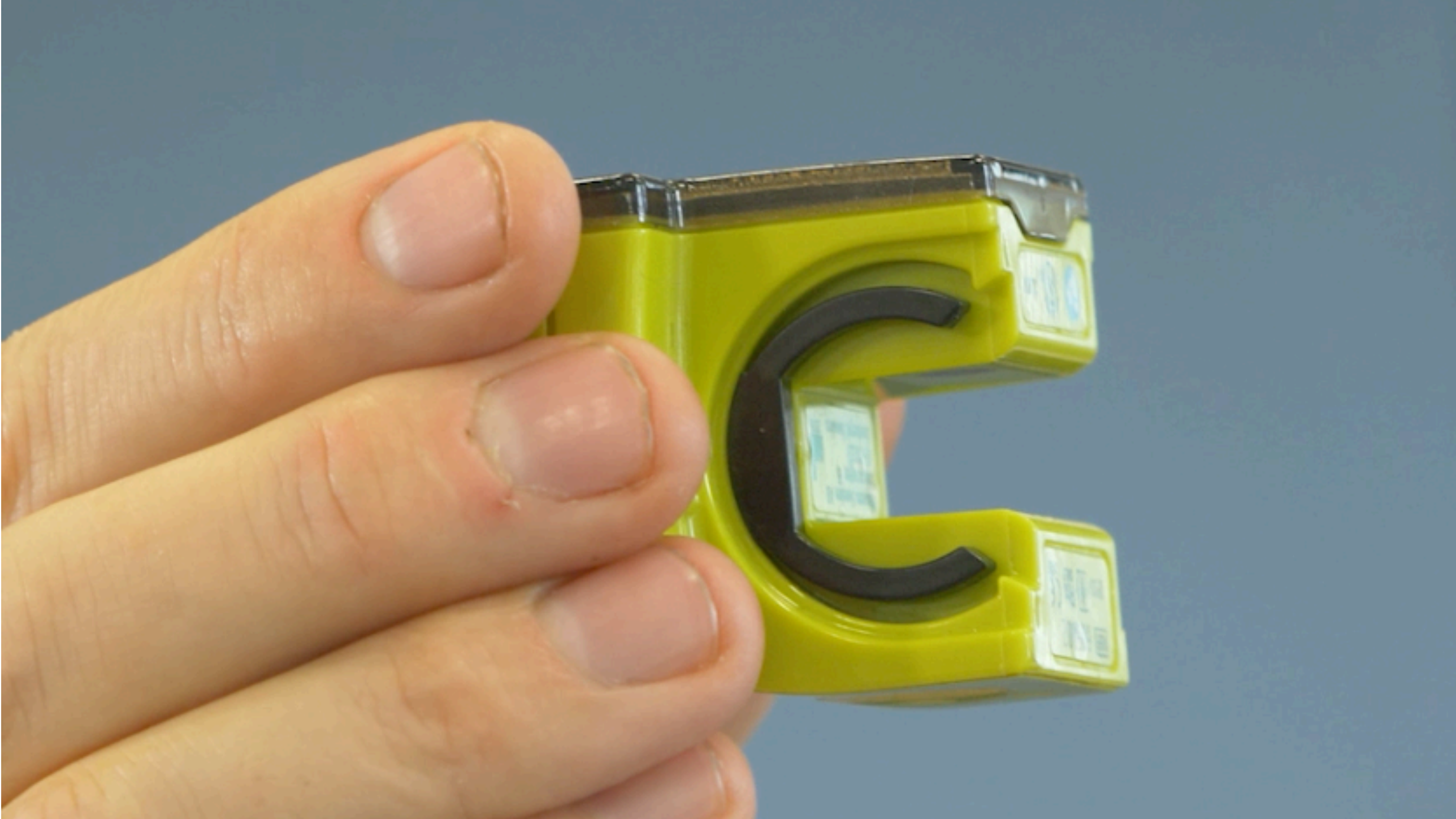


Heat returns to space in infrared.
Most is blocked by Greenhouse Gases.


FLIR
kogan
EXPERIMENT 26
REFLECTION CHARACTERISTICS
DELL
ROHDE&SCHWARZ


FLIR
kogan
EXPERIMENT 26
REFLECTION
CHARACTERISTICS
DELL

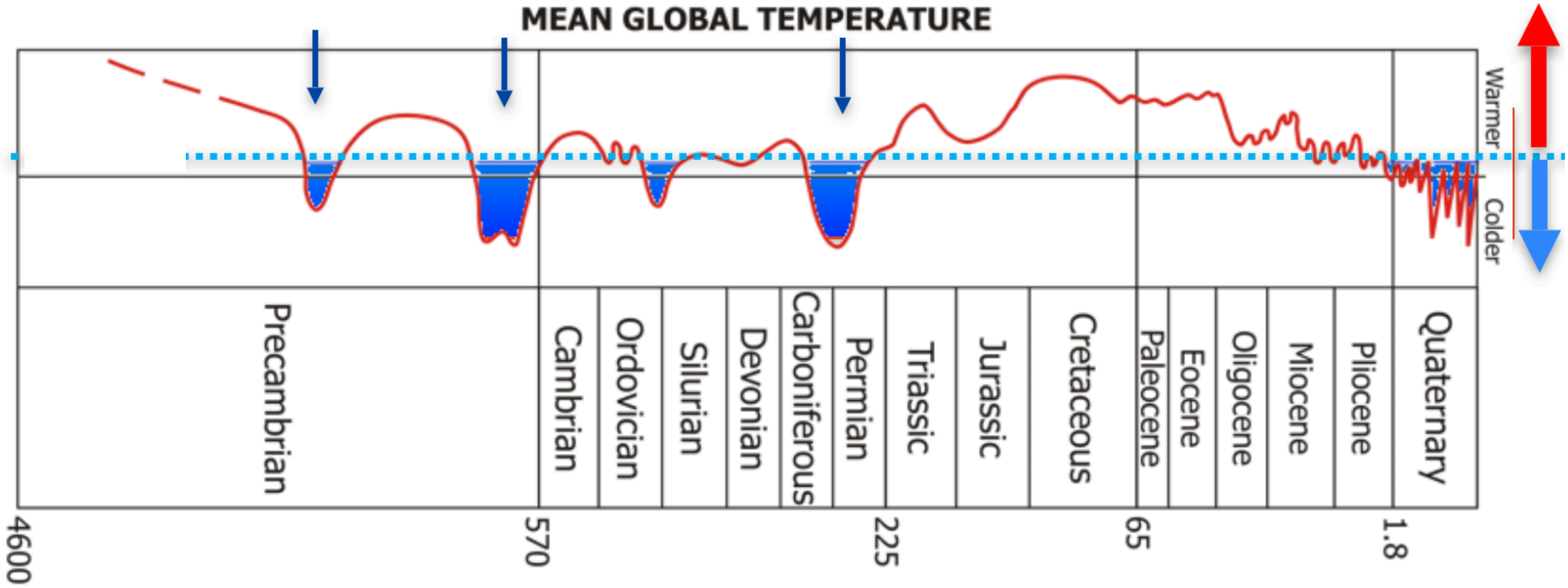




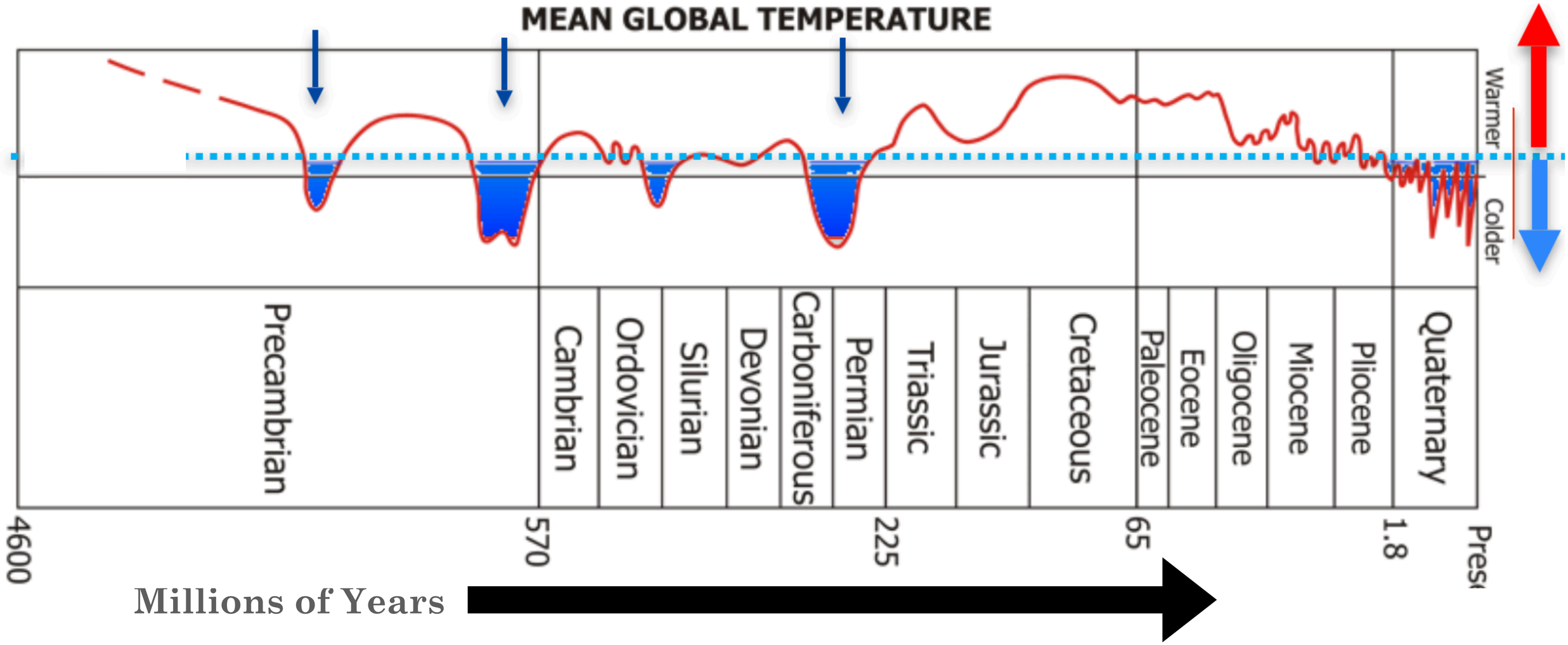
Earth's Atmosphere
Vs
Peter's Atmosphere

- Earth - (N2 78%) 21% Oxygen + 0.04% CO_2
- Peter lungs in - 21% Oxygen + 0.04% CO_2
- Peter lungs out- 17% Oxygen + 4% CO_2
- That's 100x increase in CO_2!

Earth's Temperature since Formation



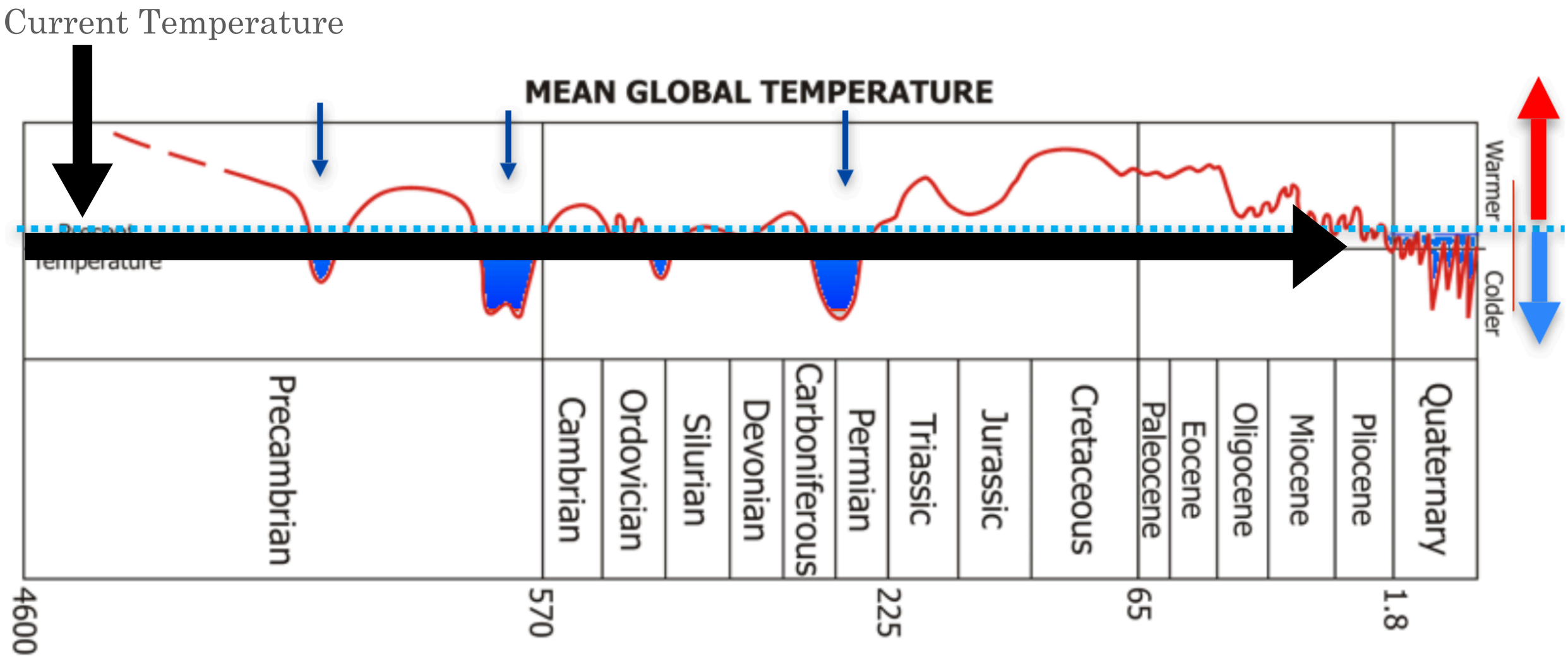
Earth's Temperature since Formation



No Polar Ice Caps

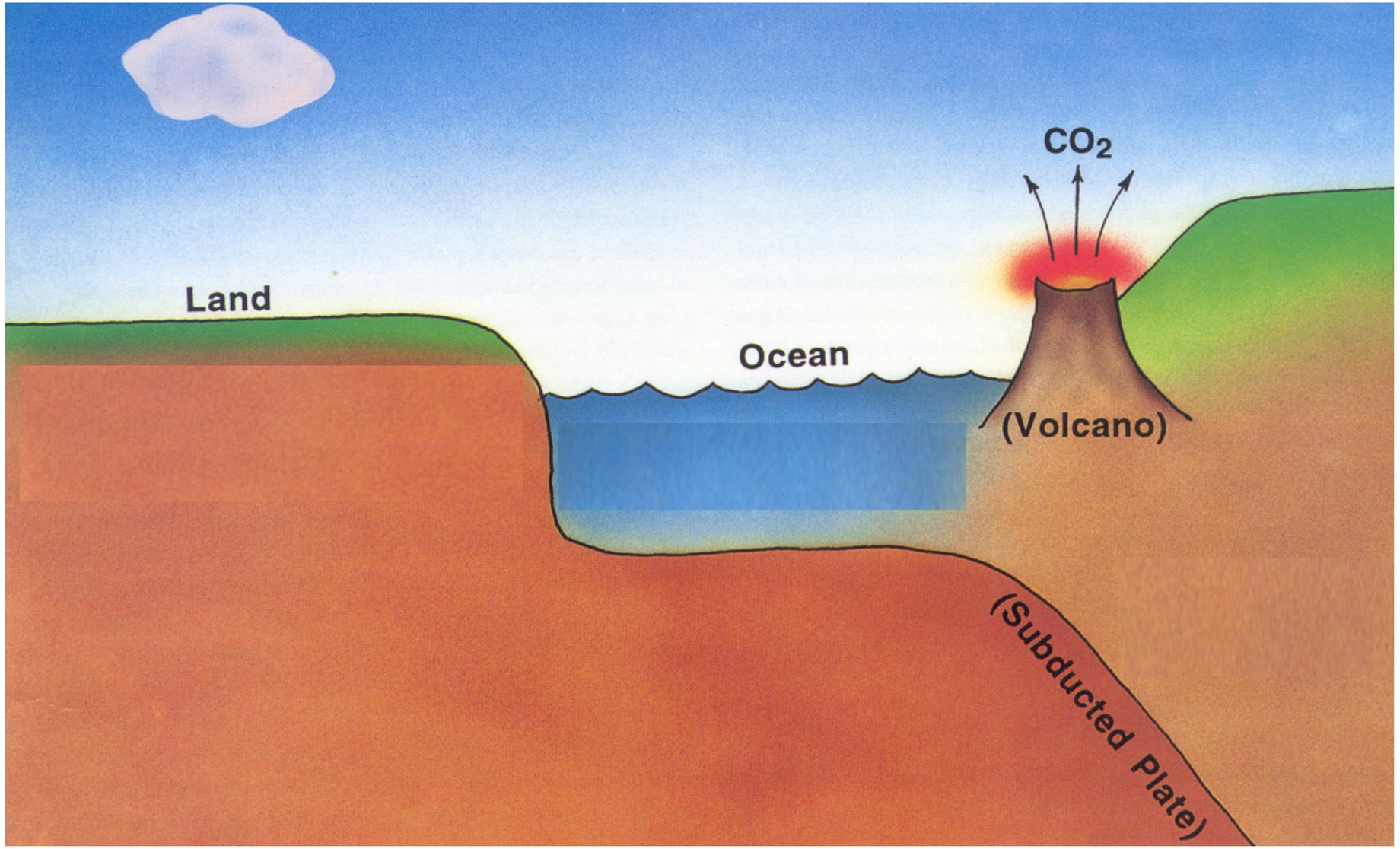
Polar Ice Caps

Today's Global Temperature

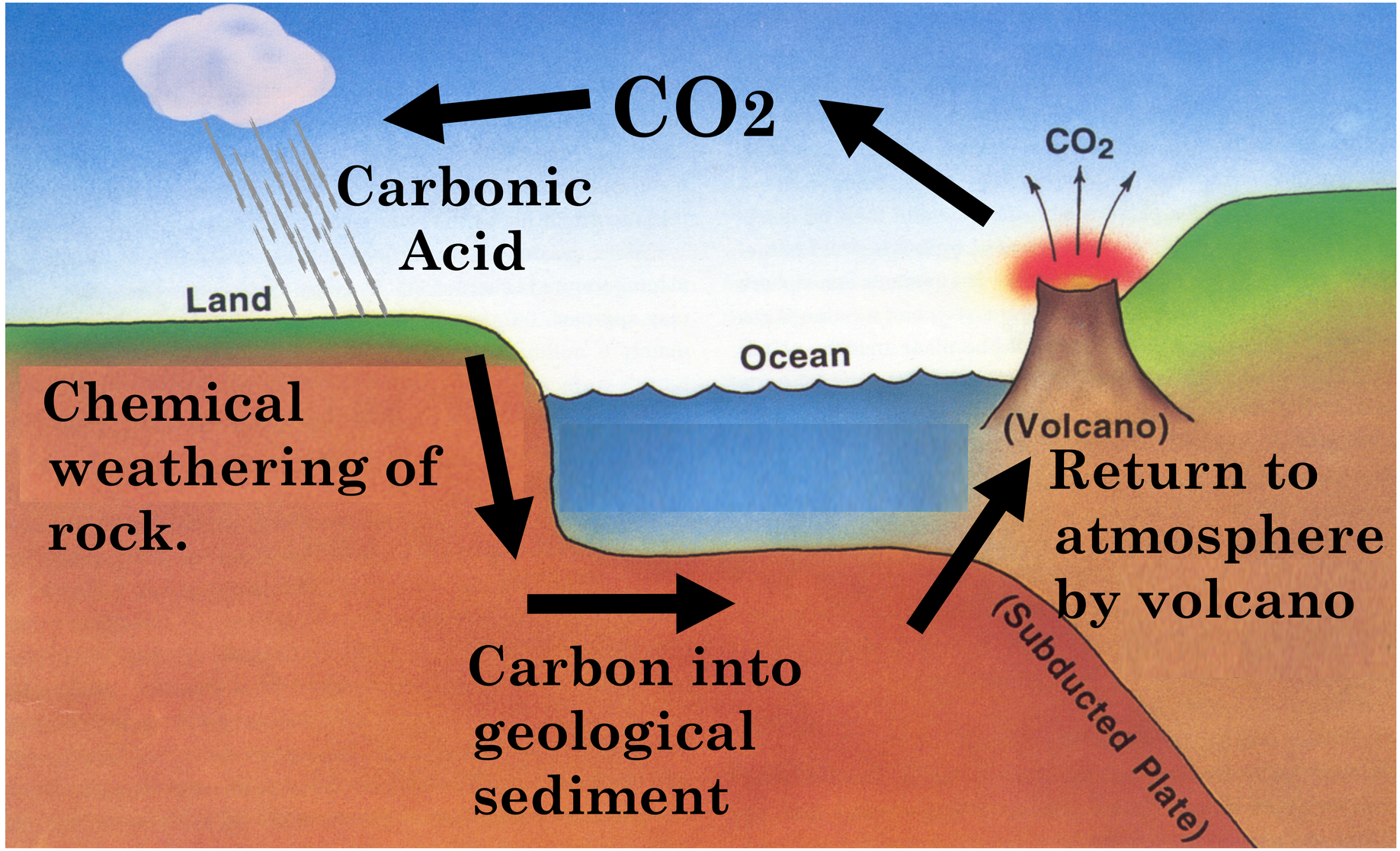


The Earth's Geological Thermostat:

The Earth's Geological Thermostat: The Carbonate-Silicate Cycle



The Earth's Geological Thermostat: The Carbonate-Silicate Cycle



The Carbonate-Silicate Cycle:
Where is the THERMOSTAT?

The Earth's Geological Thermostat: The Carbonate-Silicate Cycle

- Suppose Climate → Colder
- More surface protected under snow/ice + Less rainfall → Less weathering
- Less CO_2 removed; volcanos continue to add new CO_2. → Buildup in atmosphere
- → Greenhouse Warming

The Earth's Geological Thermostat: The Carbonate-Silicate Cycle

- Suppose Climate → Warmer
- More rain, more surface → more weathering
- More CO_2 scrubbed out so concentration decreases in atmosphere
- → Cooling

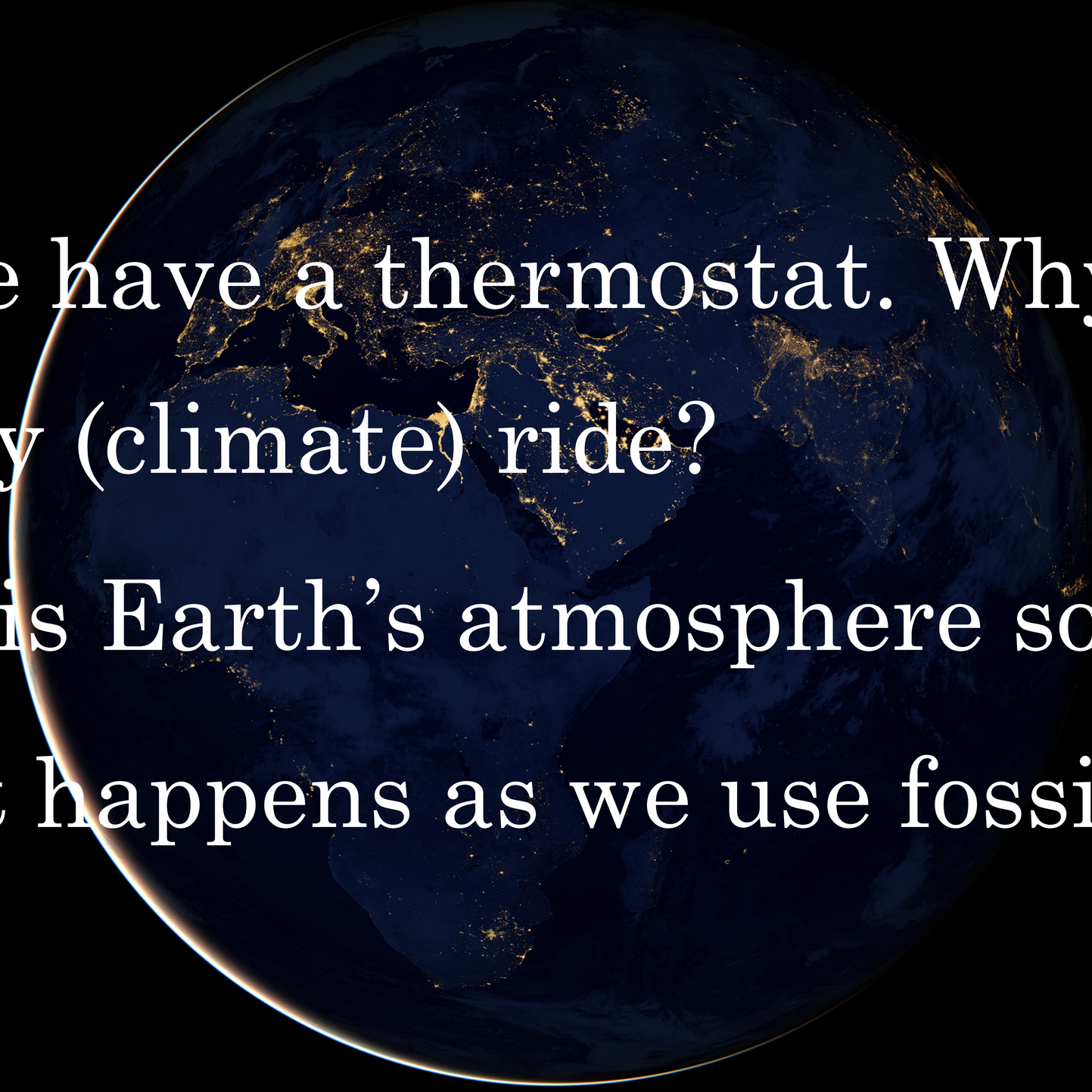
The Earth's Geological Thermostat: The Carbonate-Silicate Cycle

- **Good News!**
- Earth has a "thermostat" to regulate temp to keep water mostly liquid
- **Bad News!**
- It takes 500,000-1,000,000 years for thermostat to make adjustment
- Current Climate Change ↑↑↑↑↑ fast

The moral of the play?

- Climate change, catastrophic and irreversible, happened to both neighbours
- Terrestrial climate model physics *perfectly* predicts current Venus, Mars.
- Early Venus, Mars - models promising
- Earth has active processes that (so far) have prevented it going off the rails.

3
Black Marble



- So we have a thermostat. Why such a bumpy (climate) ride?
- Why is Earth's atmosphere so unique?
- What happens as we use fossil fuels?

Earth is Alive! We live on a Bioengineered Planet

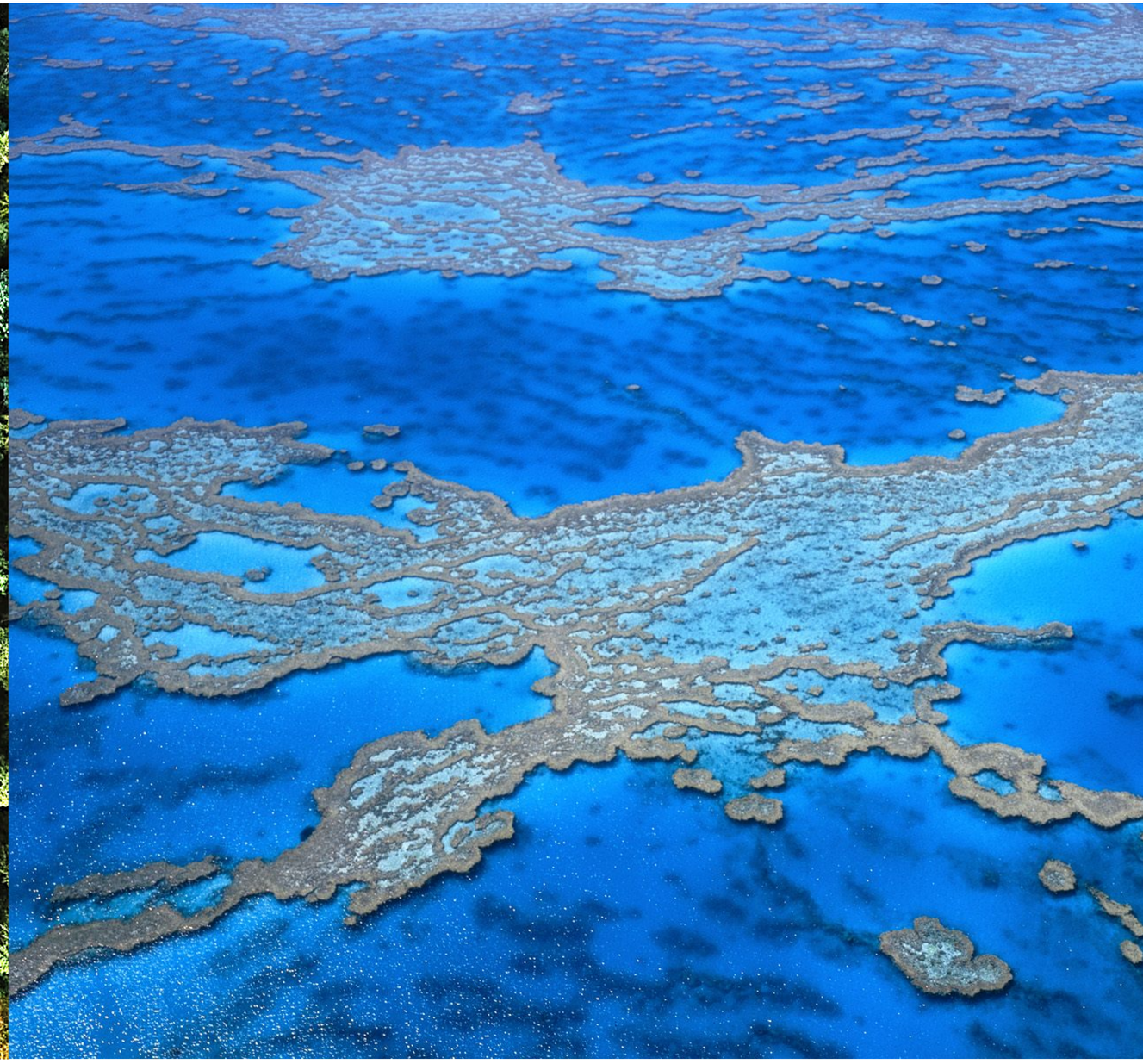
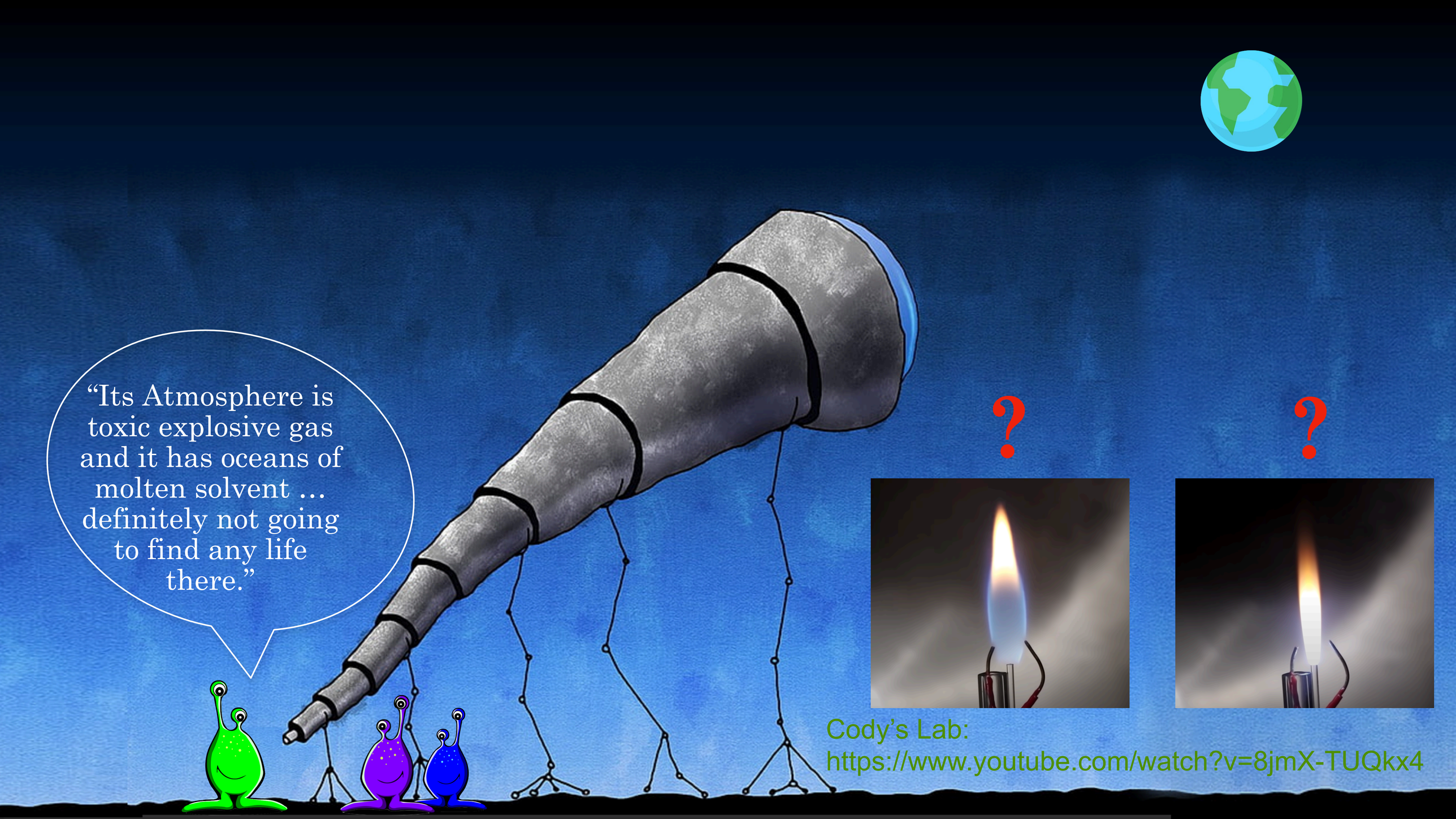


Image Credit: Unsplash

Atmosphere of Titan: Nitrogen, Methane, Ethane
Surface of Titan: Lakes of Methane with Propane, Acetylene
(also toxins like Hydrogen Cyanide)

Image Credit: NASA Cassini Mission

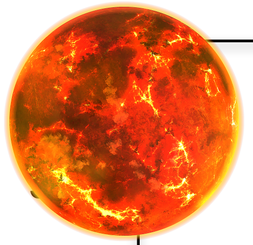

“Its Atmosphere is toxic explosive gas and it has oceans of molten solvent … definitely not going to find any life there.”
?
?
Cody’s Lab:
https://www.youtube.com/watch?v=8jmX-TUQkx4

Atmosphere: Air
Incoming Gas: Propane

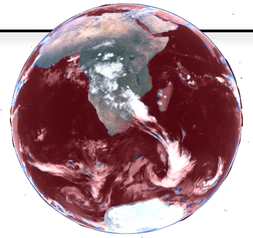
Cody’s Lab:
https://www.youtube.com/watch?v=8jmX-TUQkx4

Atmosphere: Propane
Incoming Gas: Oxygen

Cody’s Lab:
https://www.youtube.com/watch?v=8jmX-TUQkx4



Earth formed. Ball of lava.
Atmosphere: Hydrogen, Methane, Ammonia, Water.



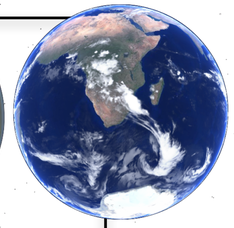
Iron rich ocean (Red marble?)

MIKKEL JUUL JENSEN/SPL/ COSMOS

"Snowball Earth" (White marble?)

Snowball?

Gondwana



Blue Marble

Atmospheric Composition

80%
70%
60%
50%
40%
30%
20%
10%

???

Nitrogen

78% N_2

Carbon Dioxide

Stromatolites (W.A.) Cyanobacteria

Banded iron

Cambrian Explosion

Snowball Earth?

Great Oxidation Event (GOE)

Huron Glaciation

"Ice Ages"

Oxygen

21% O_2

1% Argon

0.04% CO_2

4.6
4
3
2
1
0

Billions of years in the past

The University of Sydney

Putting the *fossil* in Fossil Fuels

Terrestrial plants (bogs)

Charlie Brenner Creative Commons BY-SA 2.0

Plankton on ocean floor

Image: Andria Owen

Algae in deep lakes

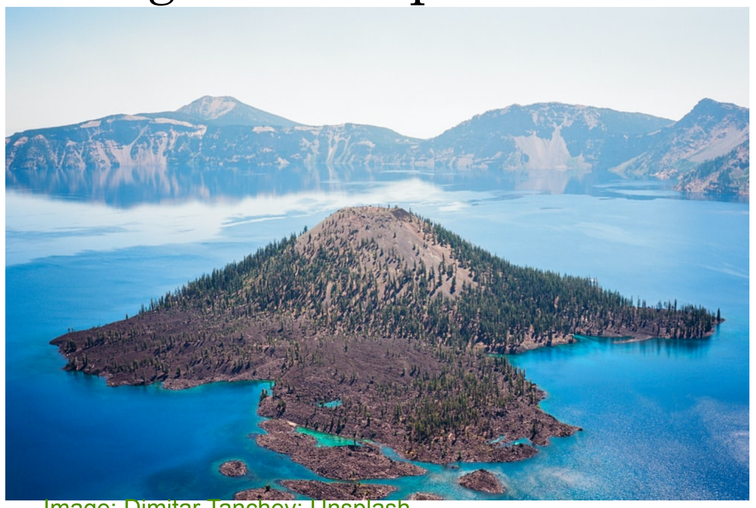


Image: Dimitar Tanchev; Unsplash

Sub-OXIC

Image: Shetland.org

Peat

ANOXIC

`Source Rocks'

sandatlas.org

Shale

ANOXIC

Time + Pressure

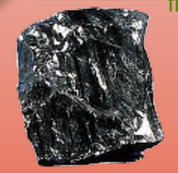
Oil

Lignite

HEAT 'Cracking'

Gas

freepngimg.com



Coal

Time + Pressure

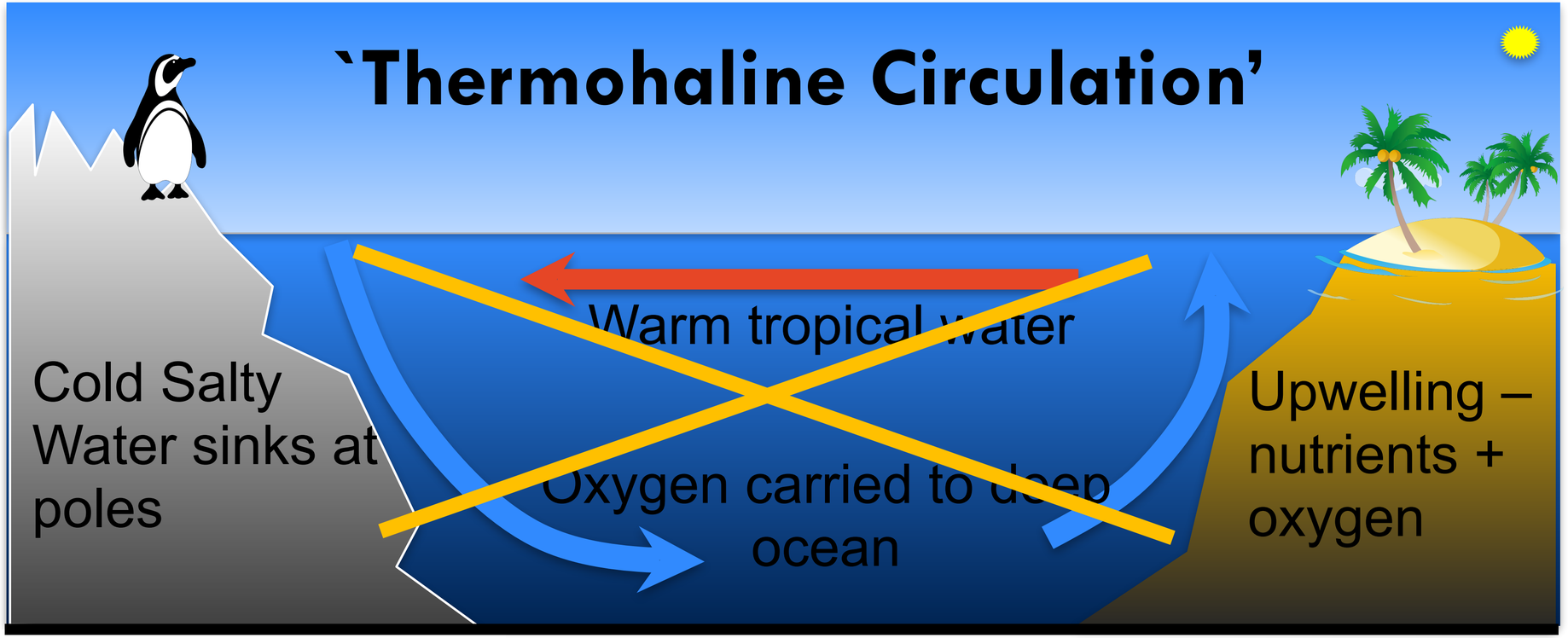
Peat bogs grow at 1mm per year.
Takes ~50 KYr for a 3m coal seam

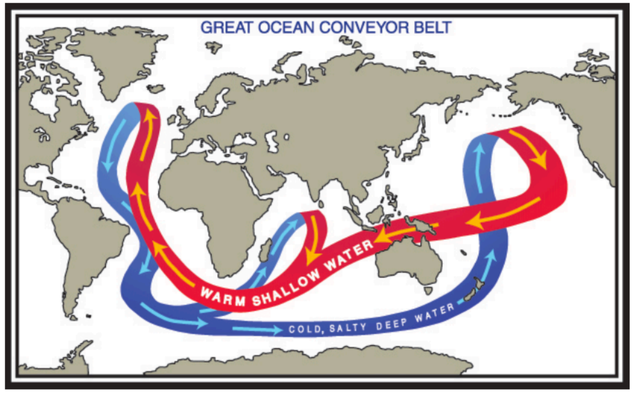
Ocean Anoxia and Oil/Gas Formation

Modern (Quaternary) ocean

Polar Ice Cap

Equator





Broecker, 1994 Nature 367,414

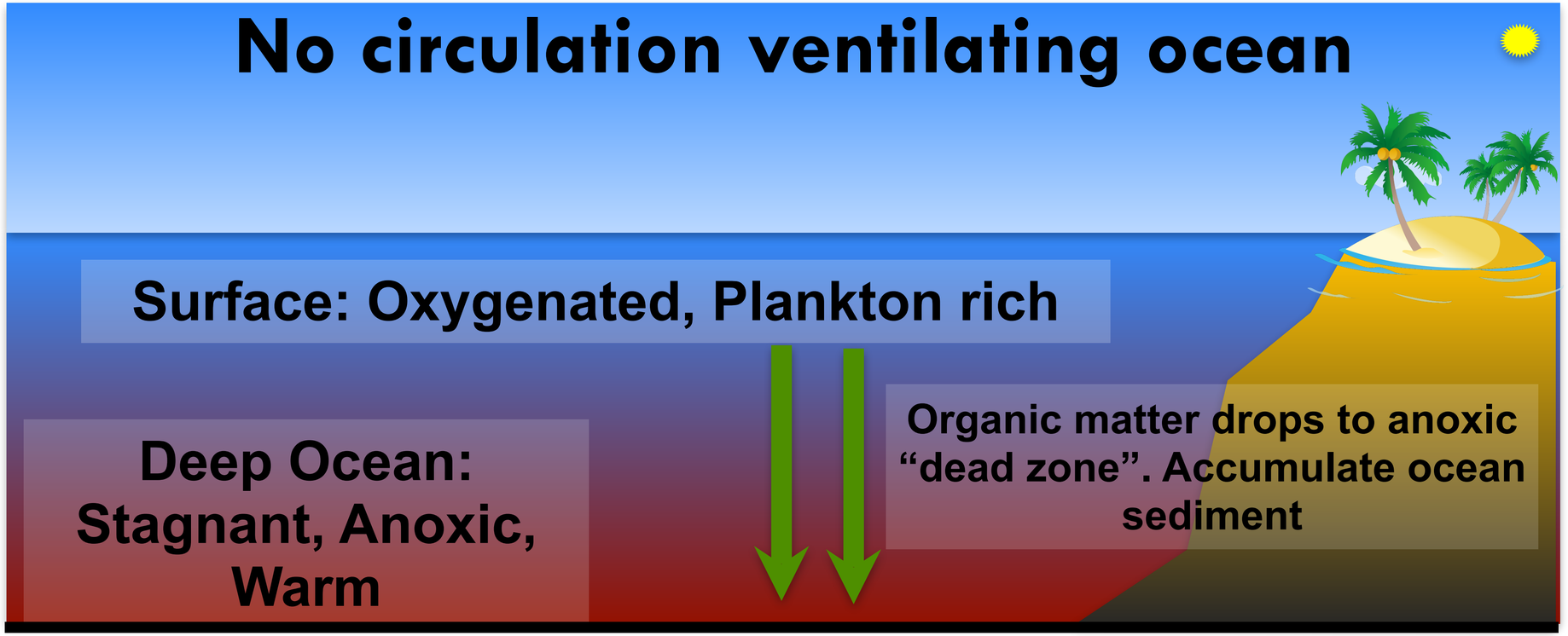
Circulation gives us the ***Gulf Stream*** and other major ocean currents.

Ocean Anoxia and Oil/Gas Formation

Mesozoic Ocean

Pole (no Ice)

Equator



Sea floor sediment

Shale `Source Rock'

Ocean Anoxia: an increasing problem today

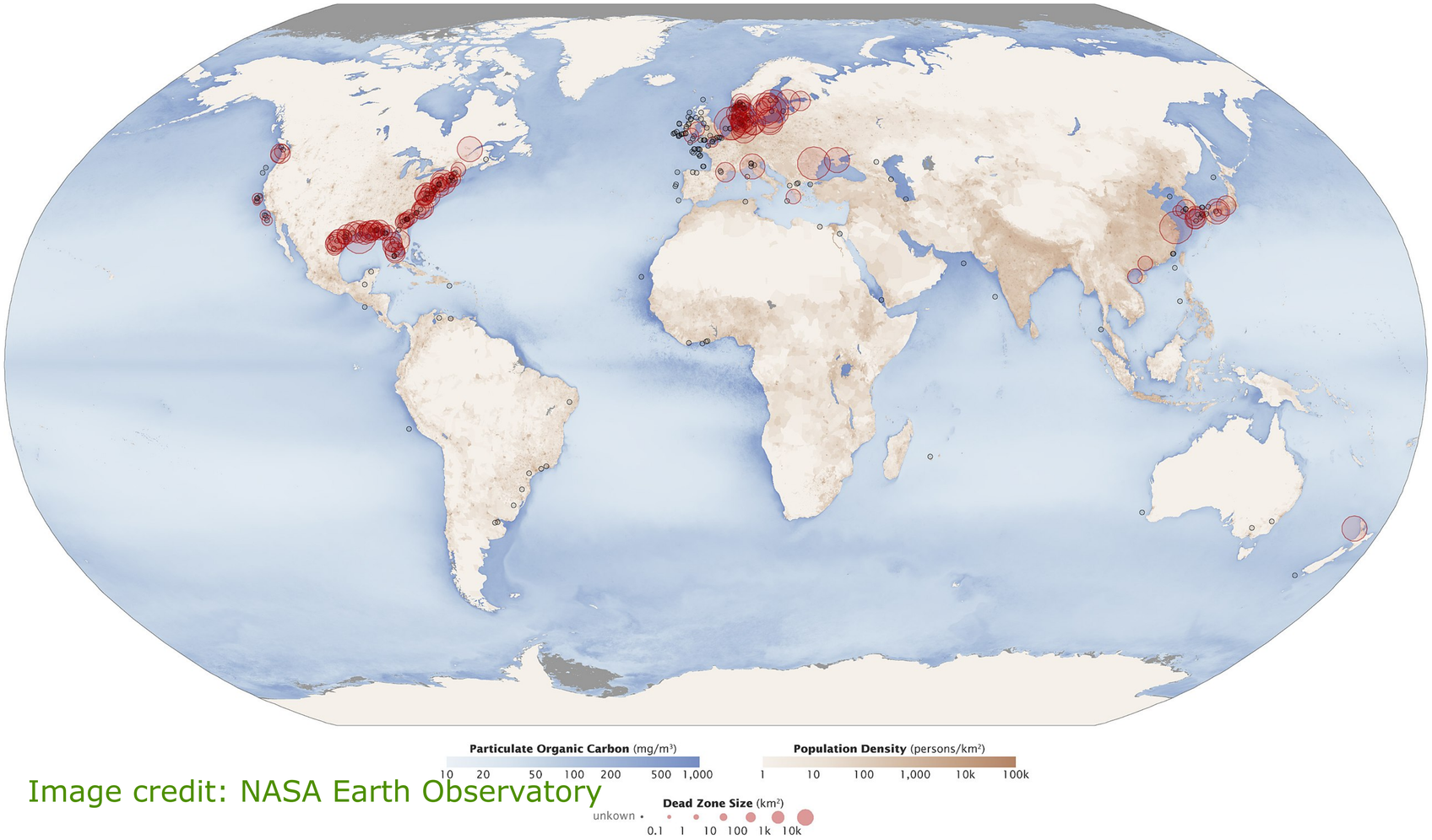


Image credit: NASA Earth Observatory

Image credit: Chris Deacutis, sailorsforthesea.org

Red Circles: Aquatic dead zones where deep water is so low in oxygen that sea life cannot survive. Anoxia has grown explosively in the past half-century (also e.g. increase in jellyfish and other low-O_2 tolerant species).

A million fish dead in 'distressing' outback algal bloom at Menindee

By Rhys Carman and Sara Tomevska

Posted Tue 8 Jan 2019 at 10:22am, updated Tue 15 Jan 2019 at 4:11pm


ABC NEWS


ABC NEWS

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doi:10.1017/S0022112005007925 Printed in the United Kingdom

Passive propulsion in vortex wakes

By D. N. BEAL[1], F. S. HOVER[1], M. S. TRIANTAFYLLOU[1], J. C. LIAO[2] AND G. V. LAUDER[2]

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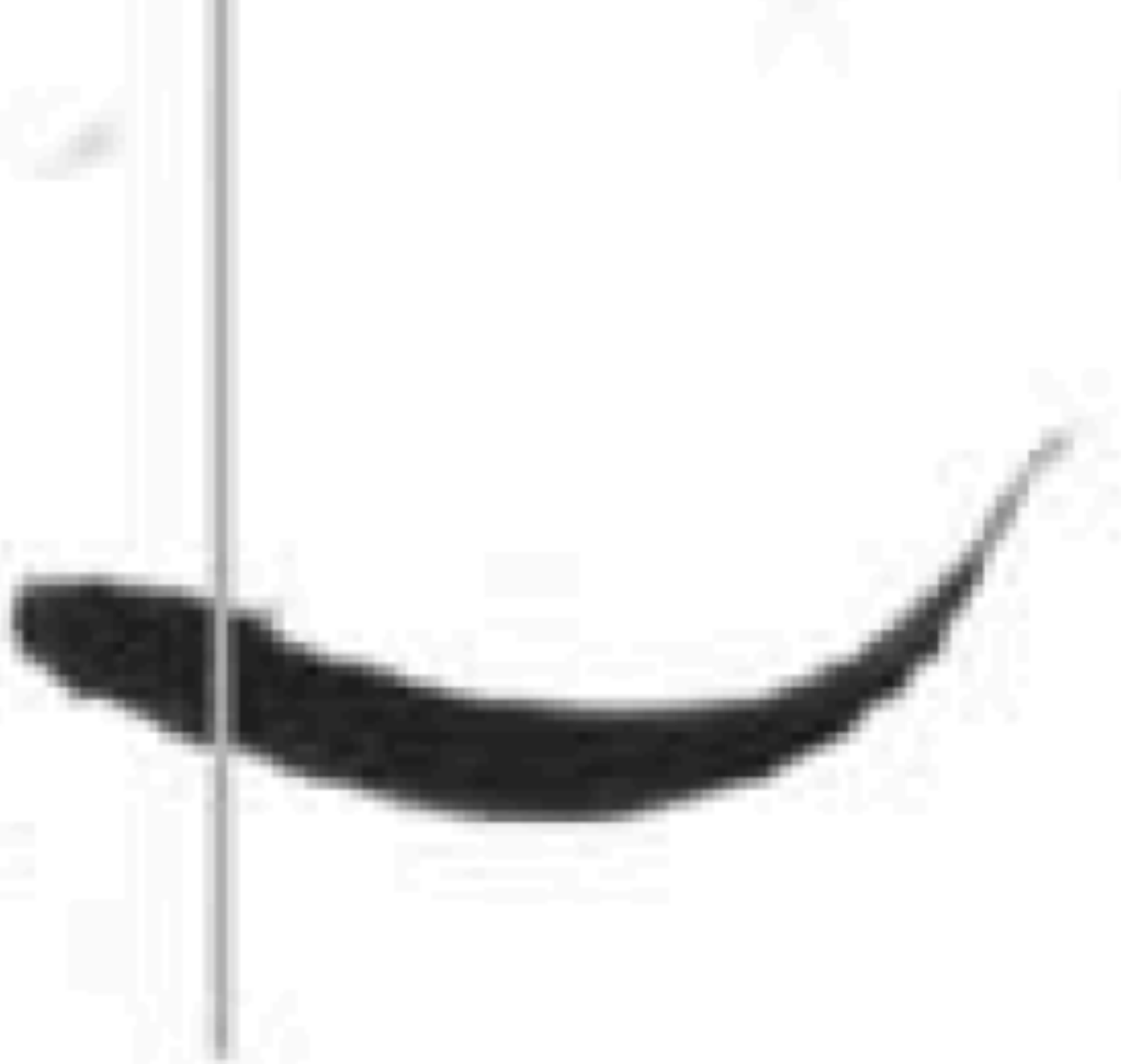
(Received 30 August 2004 and in revised form 1 August 2005)

A dead fish is propelled upstream when its flexible body resonates with oncoming vortices formed in the wake of a bluff cylinder, despite being well outside the suction region of the cylinder. Within this passive propulsion mode, the body of the fish extracts sufficient energy from the oncoming vortices to develop thrust to overcome its own drag. In a similar turbulent wake and at roughly the same distance behind a bluff cylinder, a passively mounted high-aspect-ratio foil is also shown to propel itself upstream employing a similar flow energy extraction mechanism. In this case, mechanical energy is extracted from the flow at the same time that thrust is produced.

A dead fish is pr
vortices formed in
region of the cyli

Dead Fish Swim

- NOT caused by biology, physiology, etc
- Caused by Physics & Hydrodynamics
- Magic, Perpetual Motion?
- Energy to make the fish swim comes from the moving water

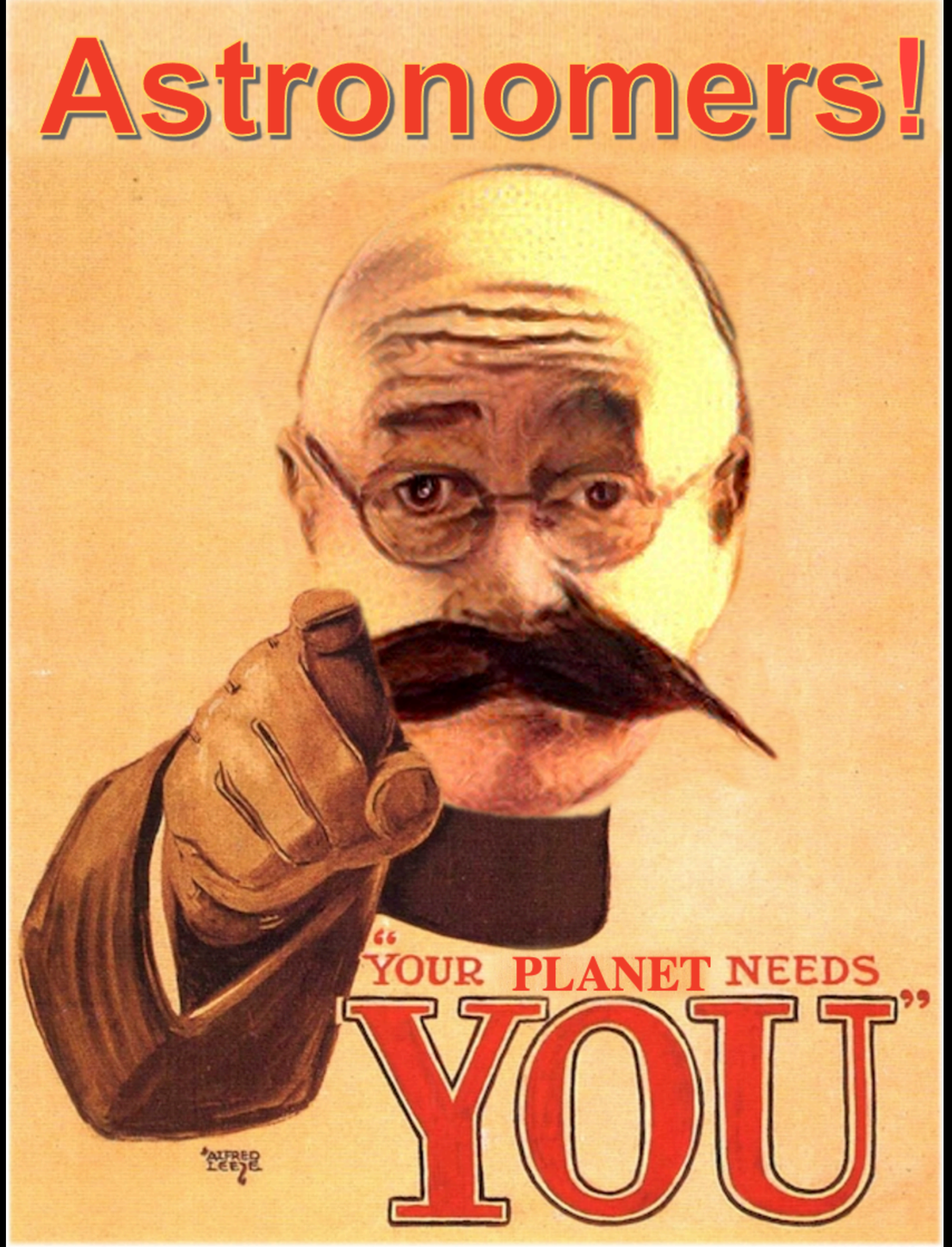


Bakkan shale oil formation
Gas flaring

North
Dakota

Image: NASA

Astronomers!



Astronomers! Spread the word!

Resources:

astronomersforplanet.earth - Astronomers for Planet Earth

www.physics.usyd.edu.au/~gekko/climate

drkarl.com/climate-change

Image: NASA